Harmonized

Calculation

Method

for

Mobile Services

(HCM-MS)

Developed by the Sub Working Group Program

Version 7

24th March 2015
(working document, diagrams under modification)

Foreword

As chairmen of the Sub Working Groups Program and Mobile Service, sub-working groups of the HCM Agreement's Technical Working Group Harmonized Calculation Method, we have the honor to present you the Version 7 of the HCM-MS program and documentation, which is in line with the HCM Agreement 2005.

This Version 7 of the HCM-MS program covers calculation methods for:

- HCM Agreement 2005
- ERMES (*)
- GSM 900 (*)
- GSM 1800 (*)
- Emergency- and Security Services (band 380-385/390-395 MHz)
- UMTS and IMT 2000 systems (*)
- Coverage
- Wideband systems

(*) Please note that not all the technical parameters of these systems are fully integrated in the HCM Agreement.

The program and its subroutines are written in FORTRAN-90.

In the documentation some pages are intentionally left blank to permit recto-verso printing. In the documentation you will find the flow charts on the left page, the text on the right page.

As chairmen of the SWG-Program and SWG-Mobile Service we would like to thank all participants of the group for their active support during the development of the new version, the program and its documentation.

Kind regards,

Peter Benner
Chairman of the Sub Working Group Program
(TWG-HCM SWG-Program)

Ivan Vander Beken
Chairman of the Sub Working Group Mobile Service
(TWG-HCM SWG-MS)

TABLE OF CONTENTS

GENERAL

This Harmonized Calculation Method for Mobile Service (HCM-MS) is part of the HCM Agreement '05. Also, the relevant CEPT Recommendations for services not noted in the HCM Agreement '05 are included in the HCM MS software, as agreed by all Signatories.

General note:

In the description (unless stated different):

all angles are in degrees,
all heights are in meters,
all distances are in kilometers,

List of common subroutines

The HCM MS V7 program uses a lot of additional subroutines. The list of the common subroutines is:

- calculation of the distance between two points (Tx and receiving point) (Calc_distance)
- calculation of the azimuth from one point to another point (Calc_direction)
- read the height of a given point from the terrain database (Point_height)
- read the morphological information of a given point from the morphological database (Point_type)
- get the profile between two points (heights or morphological information) (Tx and receiving point) (Profile)
- calculation of the gain of a directive antenna in a given direction (Antenna)
- calculate the total loss of a horizontal and/or vertical antenna (Antenna_Correction)
- convert co-ordinates to text format (CooConv)
- calculation of the clearance angle correction factor (TCA_correction_calculation)
- calculate Δh (Dh_calculation)
- calculation of the correction factor $k\Delta h$ (Dh_Correction)
- calculation of the (1kW) land- and sea field strength from curves (Get_FS_from_figures)
- get the field strength values from the figures (land and sea) (Get_figure_FS_value)
- calculation of the new co-ordinates from a given point in a given direction with a given distance (New_coordinates)
- calculation of the position of the mobile station (Position_of_mobile)

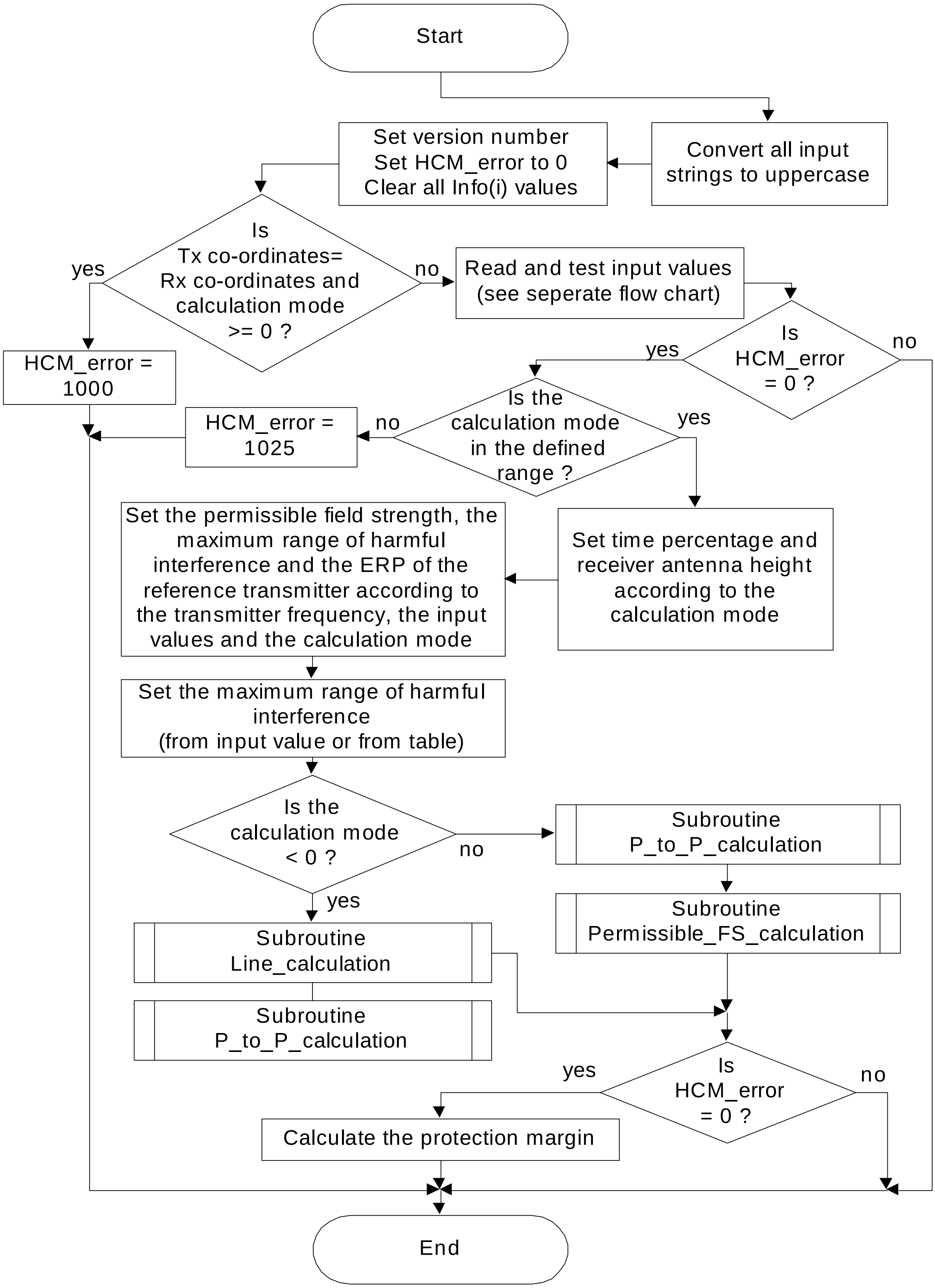
Interface

The HCM MS V7 program is only a subroutine. The interface to the HCM MS V7 is described in chapter 9.

<u>Remarks</u>:

When an error occurs, an error code is generated and the subroutine is terminated. A list of error codes and their description is given in chapter 11.

Chapter 1: HCMMS_V7 subroutine



Chapter 1: HCMMS_V7 subroutine

Description

This subroutine HCMMS_V7 is the Harmonized Calculation Method itself. The HCMMS_V7 subroutine performs calculation from a transmitting station to a receiving station or from a transmitting station to a co-ordination line. Because the HCMMS_V7 is a subroutine, a surrounding program is required to run this software. An example for a small surrounding program is given in chapter 10. A more complex surrounding program is supplied by the HCM group and can be found on the web site of the HCM Agreement.

Convert all input strings to uppercase

All input strings are converted to uppercase according to Annex 2A of the HCM Agreement.

Is Tx co-ordinates=Rx co-ordinates and calculation mode >= 0?

For point-to-point calculations it is checked, if the co-ordinates of Tx and Rx are equal. If both points are equal, no calculation can be performed and the program terminates with error 1000.

Read and test input values

This process is described in chapter 1.1.

Is the calculation mode in the defined range?

It is tested, if the calculation mode is in the range of –8 to +9. A list of the calculation mode is given on the next page.

Set time percentage and receiver antenna height according to the calculation mode

The values of the time percentage and the receiver antenna height are set according to the calculation mode and the input values (see table on next page).

Set the permissible field strength, the maximum range of harmful interference and the ERP of the reference transmitter according to the transmitter frequency, the input values and the calculation mode

Normally, the values from Annex 1 of the HCM Agreement 2005 are taken; these values can be overwritten by input values.

Table of calculation parameters

C_mode	Type of calculation	Perm. field strength [dBμV/m]	Applied T%	Applied h_2
+9	UMTS / IMT2000	21	1 or 10 *	Noc
+8	Emergency and security services (380 to 400 MHz) (narrow band systems only)	18	1 or 10 *	Noc
+7	Normal HCM Agreement ** (coverage)	Table	50	Noc
+6	GSM1800 - GSM 1800 (ML)	42	10	Noc
+5	GSM 1800 - GSM 1800 (BS)	38	10	Noc
+4	ERMES – ERMES	32	10	3
+3	GSM900 – NMT	32	10	Noc
+2	GSM900 – TACS	32	10	Noc
+1	GSM900 – GSM900	32	10	Noc
0	Normal HCM Agreement **	Table	1 or 10 *	Noc
-1	(border) line normal HCM Agreement	Table	1 or 10 *	10
-2	(border) line GSM900	19	10	3
-3	(border) line ERMES	12	10	3
-4	(border) line ERMES	32	10	3
-5	(border) line ERMES	52	50	3
-6	(border) line GSM1800	25	10	3
-7	(border) line Emergency and security services (380 to 400 MHz)	18	1 or 10 *	10
-8	UMTS / IMT2000	21	1 or 10 *	3

Noc = no change
* = derived from input value 10Z (Channel occupation)
Table = Table of Annex 1 of the HCM Agreement
** Normal HCM Agreement calculation mode means calculation for all services not covered by special calculation mode (for example GSM, UMTS/IMT 2000, Emergency and security services)

Set the maximum range of harmful interference (from input value or from table)

If no input value is available, the maximum range of harmful interference is taken from the table in Annex 1. If an input value is available, this value is taken.

Is the calculation mode < 0?

A decision is made, if it is a line calculation (calculation mode is negative) or a point-to-point calculation (calculation mode is 0 or positive).

Subroutine P_to_P_calculation

If the calculation mode is 0 or positive, a point-to-point calculation is performed. This process is described in chapter 2.

Subroutine Permissible_FS_calculation

The permissible field strength is calculated. This process is described in chapter 4.

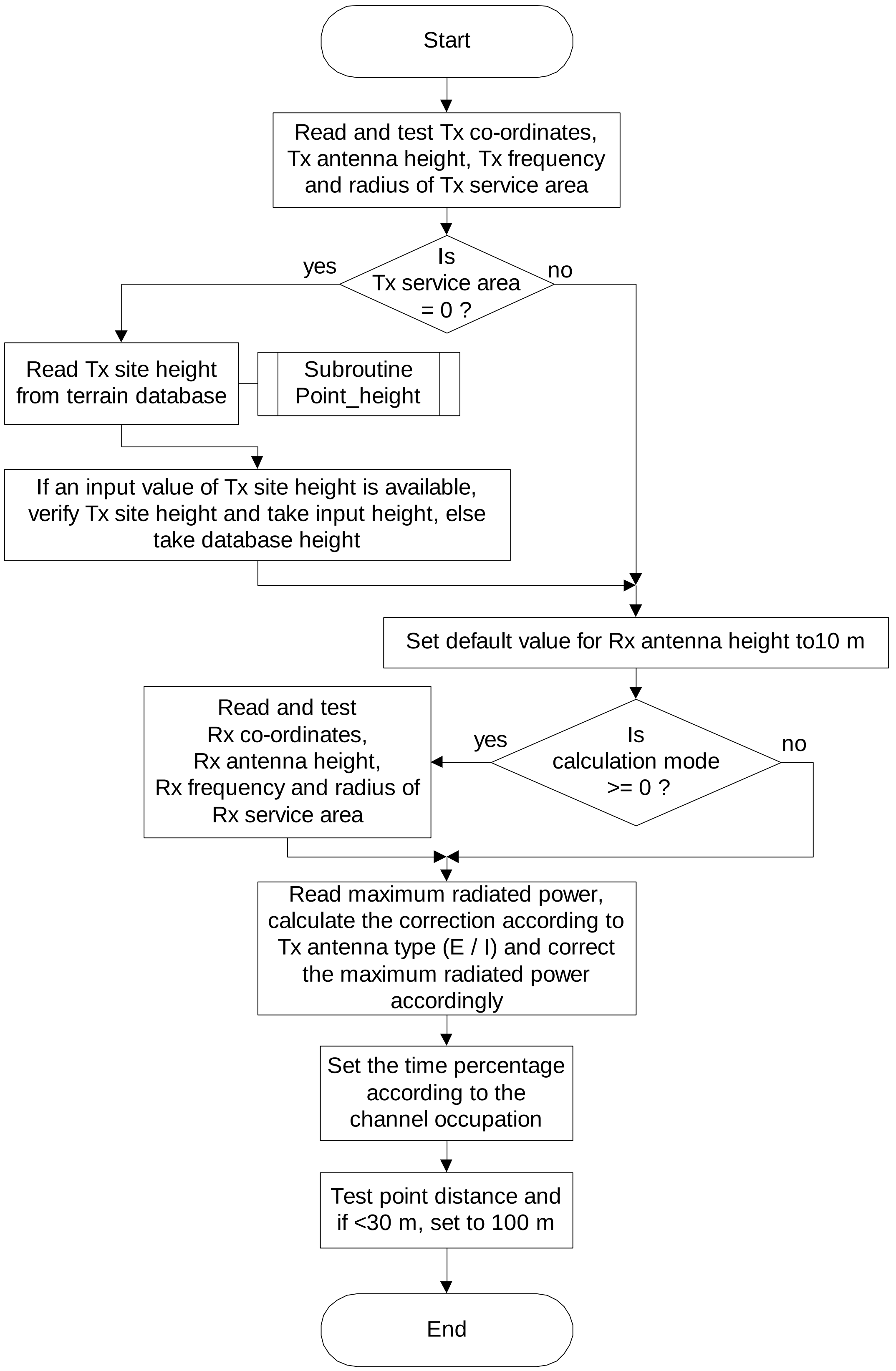
Subroutine Line_calculation

The maximum field strength on a line or the cross-border field strength is calculated. This process is described in chapter 3. This subroutine is using the subroutine P_to_P_calculation.

Calculate the protection margin

The protection margin is calculated. It is the permissible field strength minus the calculated field strength.

Chapter 1.1: Read and test input values



Chapter 1.1: Read and test input values

Read and test Tx co-ordinates, Tx antenna height, Tx frequency and radius of Tx service area

The Tx data is read and tested. If an error in the format of data occurs, an HCM_error code is generated (see chapter 11).

Read Tx site height from terrain database

The site height of Tx is read from the terrain database with the Point_height subroutine. This subroutine is described in chapter 5.3.

If an input value of Tx site height is available, verify Tx site height and take input height, else take database height

If an input value for the Tx site height is available, this input height is compared with the height of the terrain database. If the heights differ, an Info(i) value is set depending on the difference value.

Read and test Rx co-ordinates, Rx antenna height, Rx frequency and radius of Rx service area

In case of point-to-point calculations, the Rx values are read and tested if an error in the format of data occurs; an HCM_error code is generated (see chapter 11).

Read maximum radiated power, calculate the correction according to Tx antenna type (E / I) and correct the maximum radiated power accordingly

The value of the maximum radiated power is read, tested and if the type of the antenna is ‘I’, this value is reduced by 2.1 dB.

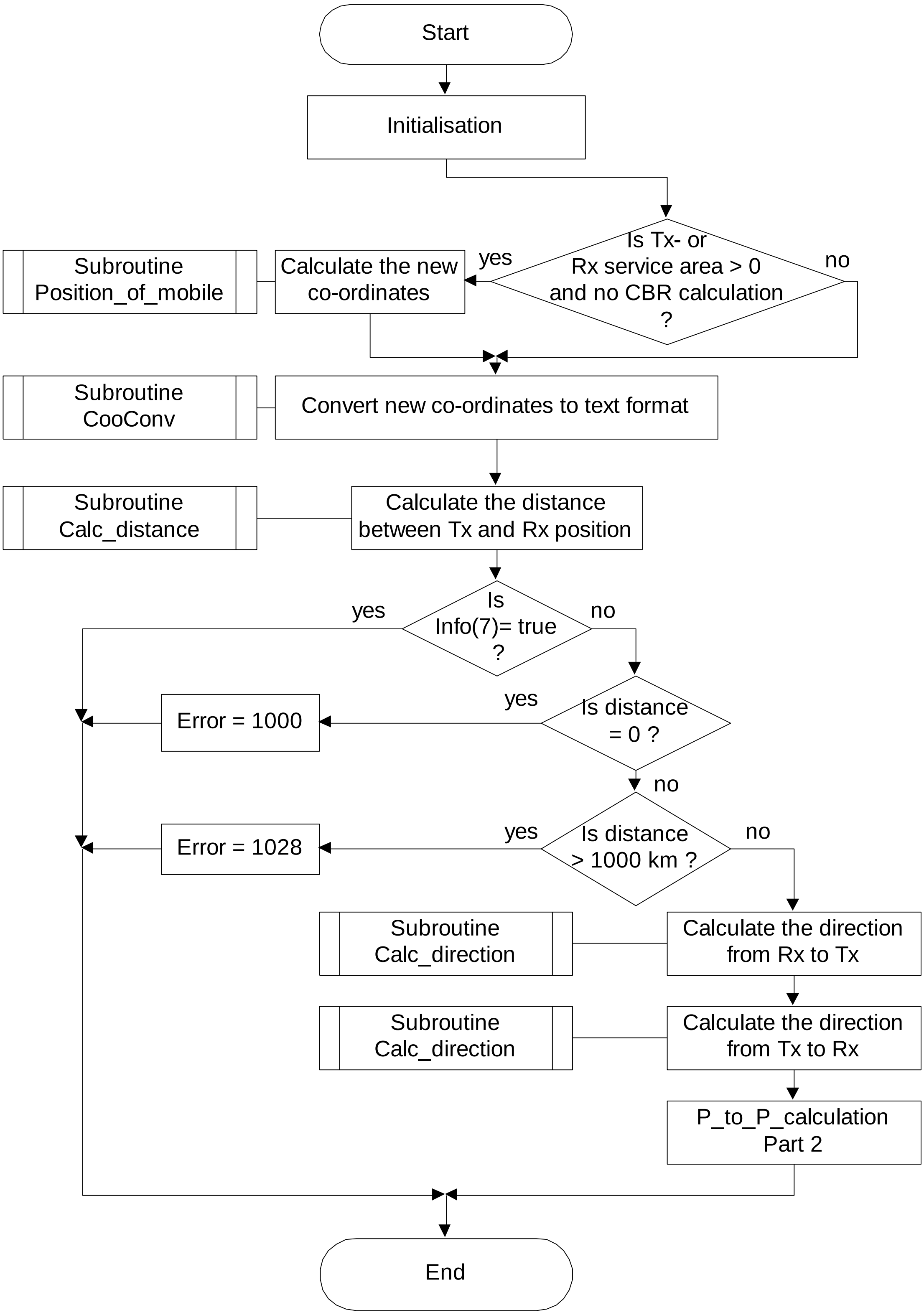
Set the time percentage according to the channel occupation

If the channel occupation is 1, than the time percentage is set to 1 %, else it is set to 10 %.

Test point distance and if <30 m, set to 100 m

The point distance for the profile is an input value (PD) and is normally 100 m. If this value is less than 30 m, it is set to the default value of 100 m. For harmonised calculations the point distance should be set to 100 m. The default value of 100 meter is choosen because the grid size of the HCM topo data is 3” by 3” or 3” by 6”, which is approximately 100 m.

Chapter 2: Subroutine P_to_P_calculation
Part 1



Chapter 2: Subroutine P_to_P_calculation

Part 1

Initialisation

The new coordinates for Tx and Rx in a first step are set to the input values. All info values existing in this subroutine are cleared.

Calculate the new co-ordinates

The new co-ordinates of Tx and / or Rx are calculated with the subroutine Position_of_mobile. This subroutine is described in chapter 2.1. The new co-ordinates are only calculated with the Position_of_mobile subroutine, if there is no cross-border calculation! In case of cross-border calculation, the position of a mobile Tx is calculated in the subroutine CBR_Cooordinates which is described in chapter 3.1.

Convert the new co-ordinates to text format

The new calculated co-ordinates are converted from internal decimal format to text format with the subroutine CooConv. This subroutine is described in chapter 5.8. Co-ordinates are converted because they are given as an output value in degrees, minutes and seconds.

Calculate the distance between Tx and Rx position

The distance between Tx and Rx position is calculated with the subroutine Calc_distance. This subroutine is described in chapter 5.1.

Is Info(7) = True?

If in the subroutine Position_of_mobile an overlapping situation was encountered, the Info(7) was set to True and the fieldstrenght was set to 999.9. For this situation no further calculation is required.

Is distance = 0?

This is the case when Tx and Rx are both fixed stations and have the same co-ordinates. An error 1000 is given and the program ends.

Is distance > 1000 km?

The range of the propagation curves is limited to 1000 km, so no calculation is possible beyond this distance.

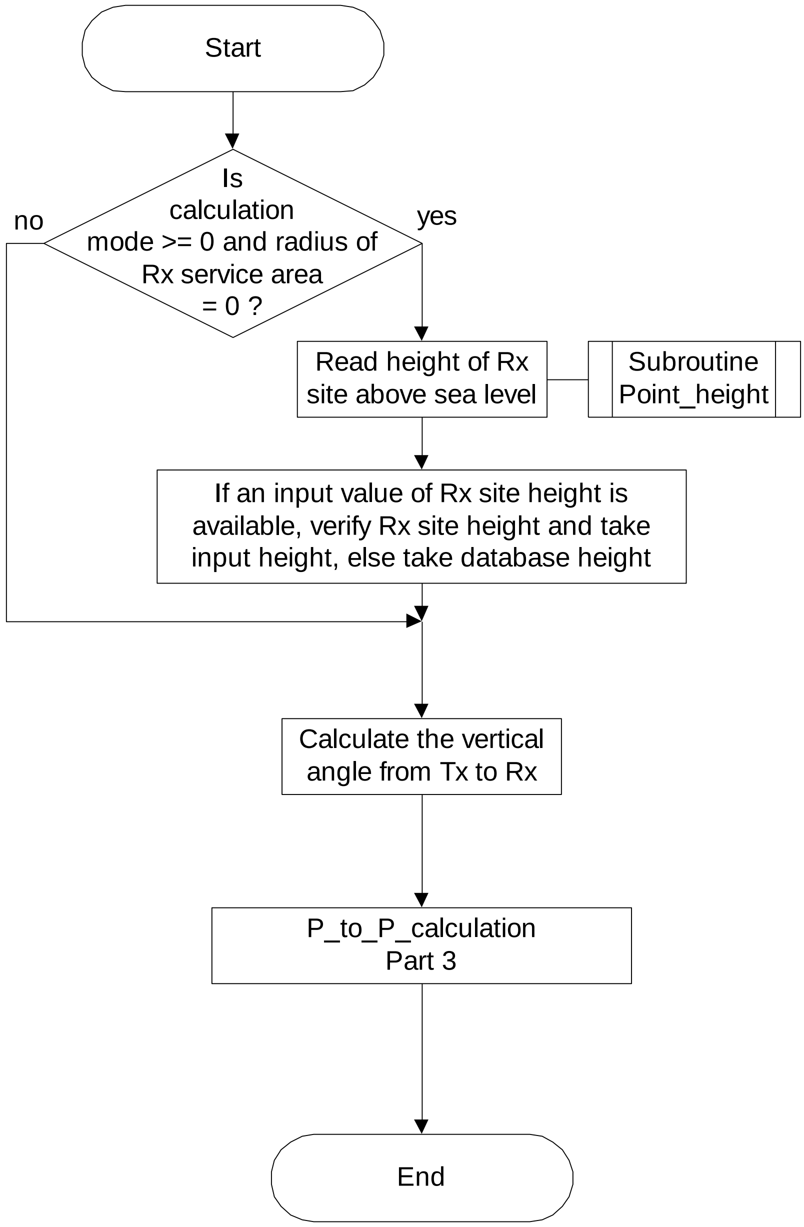
Calculate the direction from Rx to Tx
Calculate the direction from Tx to Rx

The directions are calculated with the subroutine Calc_direction. This subroutine is described in chapter 5.2.

P_to_P_calculation Part 2

This process is described in the next flow chart.

Chapter 2: Subroutine P_to_P_calculation
Part 2



Subroutine P_to_P_calculation

Part 2

Read Rx site height from terrain database

If there is a point-to-point calculation and the Rx is not a mobile, the site height of Rx is read from the terrain database with the Point_height subroutine. This subroutine is described in chapter 5.3.

If an input value of Rx site height is available, verify Rx site height and take input height, else take database height

If an input value for the Rx site height is available, this input height is compared with the height of the terrain database. If the heights differ, an Info(i) value is set depending on the difference value.

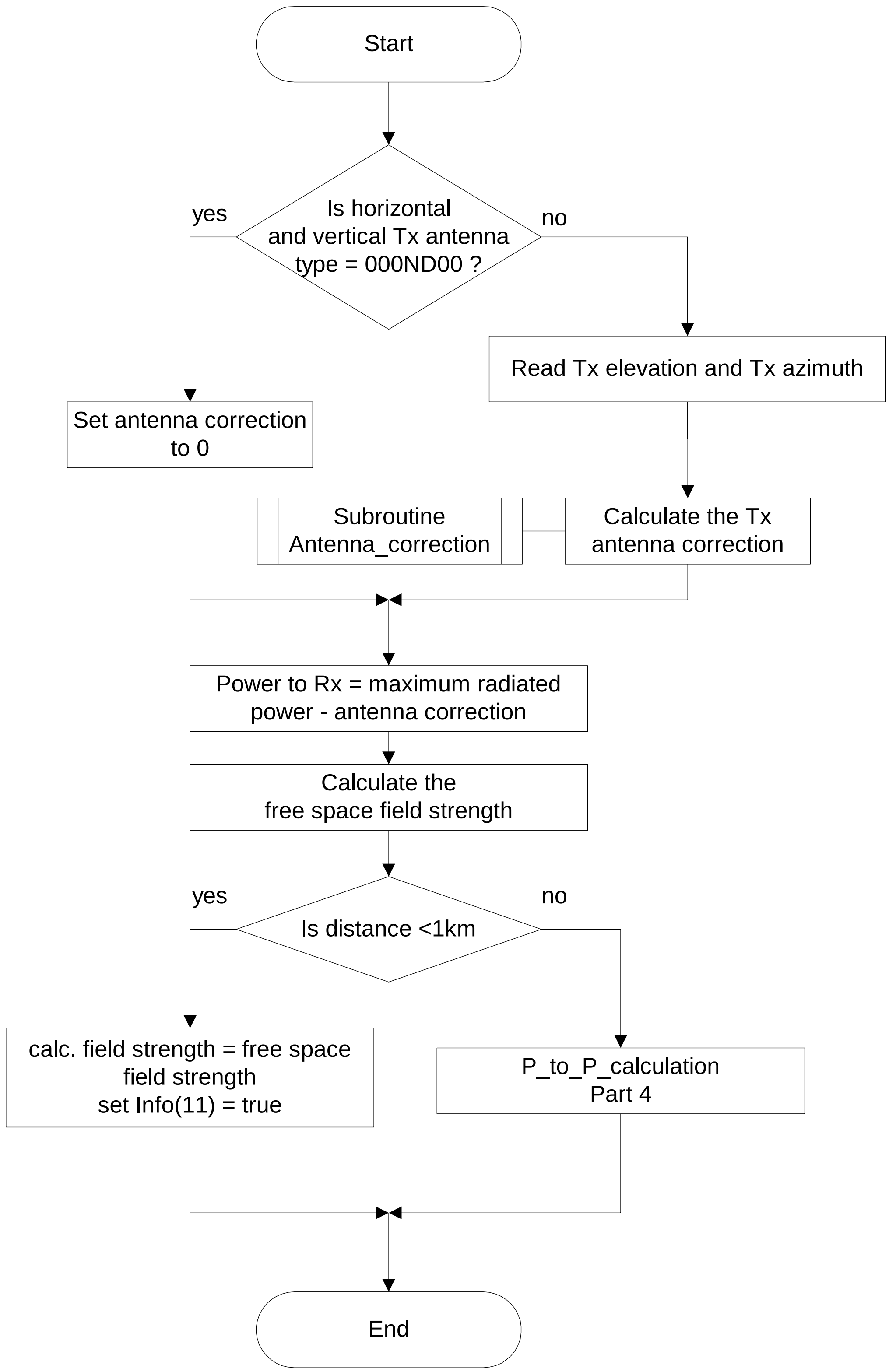
Calculate the vertical angle from Tx to Rx

The vertical angle from Tx to Rx is calculated.

P_to_P_calculation Part 3

This process is described in the next flow chart.

Chapter 2: Subroutine P_to_P_calculation
Part 3



Subroutine P_to_P_calculation

Part 3

Is horizontal and vertical Tx antenna type = 000ND00?

If the Tx antenna is a non directional antenna, the antenna correction is set to 0, else the antenna correction is calculated.

Calculate the Tx antenna correction

Taking into account the horizontal and vertical antenna types and the horizontal and vertical difference angles, the antenna correction of the Tx antenna is calculated with the Antenna_correction subroutine. This subroutine is described in chapter 5.7.

Calculate the free space field strength

The free space field strength is calculated with the formula:
Free space field strength = 77.0 – 20 * LOG (Distance) + Power to Rx

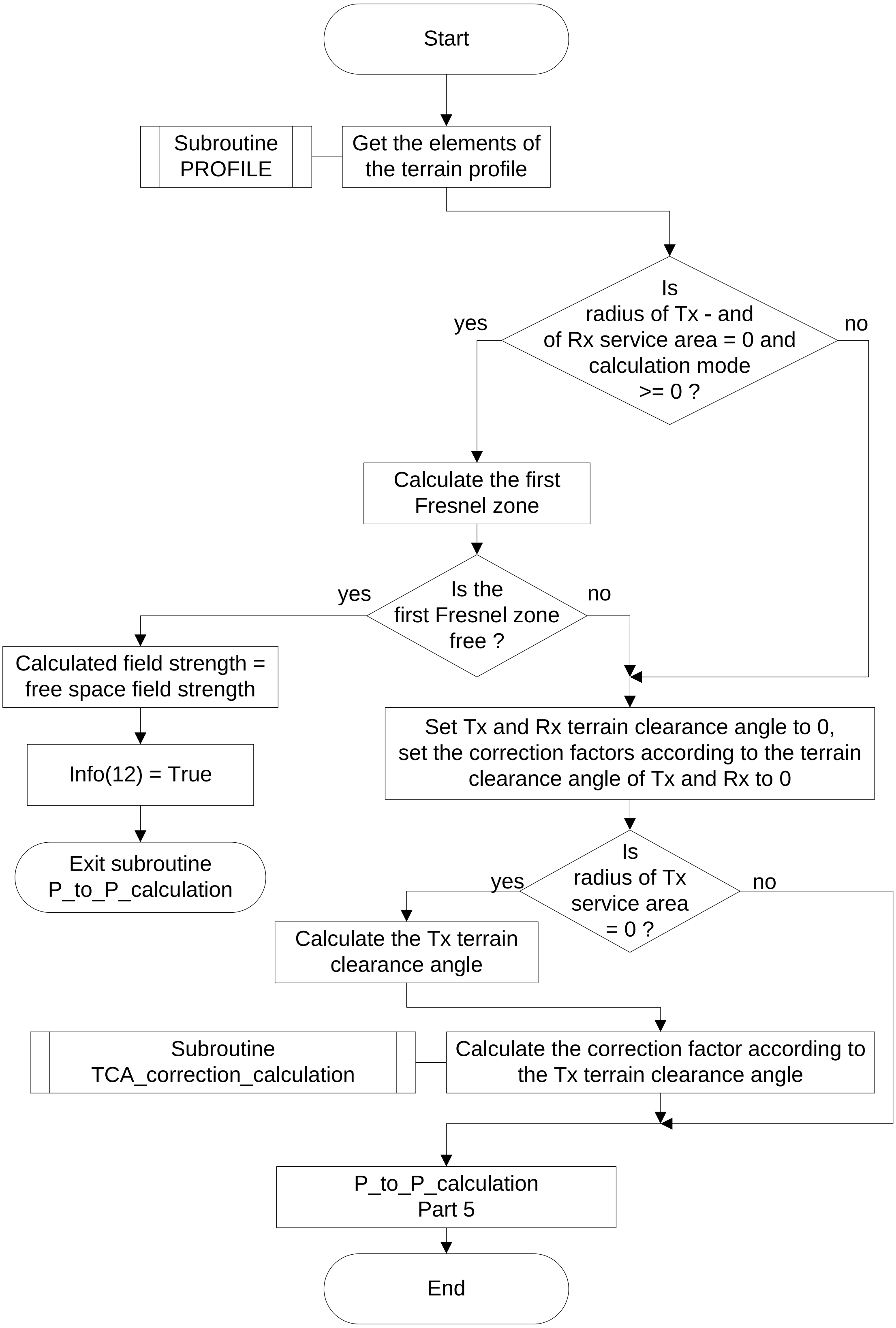
Calculated field = free space field strength
set info (11) = true

The calculated field strength is set equal to the free space field strenght for distances less than 1 km, because the propagation curves only start at 1 km. The Info(11) value is set to indicate this situation.

P_to_P_calculation Part 4

This process is described in the next flow chart.

Chapter 2: Subroutine P_to_P_calculation
Part 4



Subroutine P_to_P_calculation

Part 4

Get the elements of the terrain profile

Between Tx and Rx position, all terrain heights in a defined grid are read from the terrain database. This is done with the PROFILE subroutine. This subroutine is described in chapter 5.5.

Calculate the first Fresnel zone

Only if Tx and Rx are fixed stations and only in the case of a point to point calculation, the first Fresnel zone is calculated and it is checked, if it is free. If it is free, the calculated field strength is set equal to the free space field strength and the Info(12) value is set to indicate this situation.

Calculate the Tx clearance angle

If Tx is a fixed station, the terrain clearance angle is calculated.

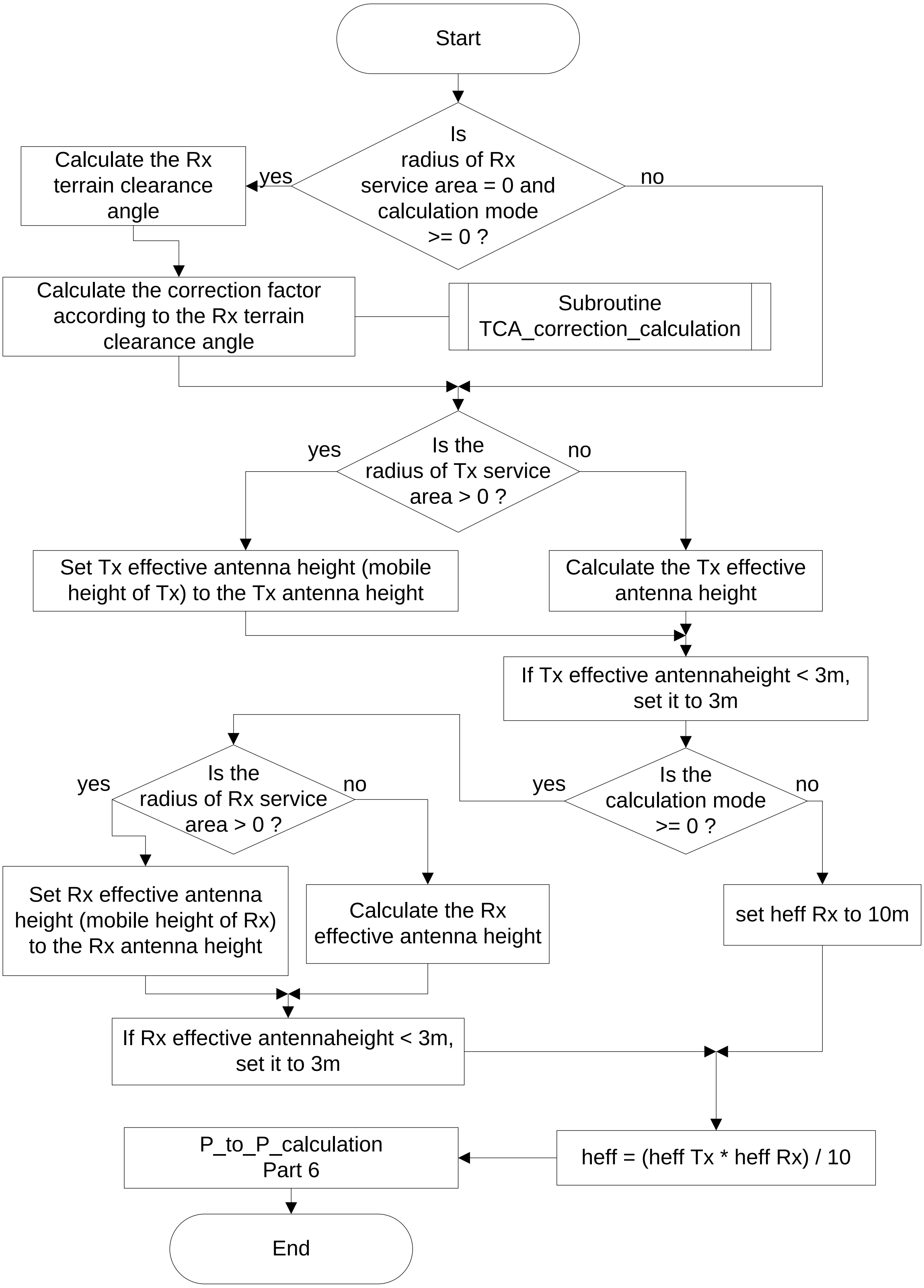
Calculate the correction factor according to the Tx terrain clearance angle

The correction factor according to the Tx terrain clearance angle is calculated with the subroutine TCA_correction_calculation. This subroutine is described in chapter 5.9.

P_to_P_calculation Part 5

This process is described in the next flow chart.

Chapter 2: Subroutine P_to_P_calculation
Part 5



Subroutine P_to_P_calculation

Part 5

Calculate the Rx clearance angle

If Rx is a fixed station and it is a point-to-point calculation, the terrain clearance angle is calculated.

Calculate the correction factor according to the Rx terrain clearance angle

The correction factor according to the Rx terrain clearance angle is calculated with the subroutine TCA_correction_calculation. This subroutine is described in chapter 5.9.

Is the radius of Tx service area > 0?

If the Tx is a mobile, the effective antenna height of the Tx is set to the input value of the Tx antenna height, else the effective antenna height of the Tx is calculated.

Is the radius of Rx service area > 0?

Only in case of a point-to-point calculation, it is checked if the Rx is a mobile.
If the Rx is a mobile, the effective antenna height of the Rx is set to the input value of the Rx antenna height, else the effective antenna height of the Rx is calculated.

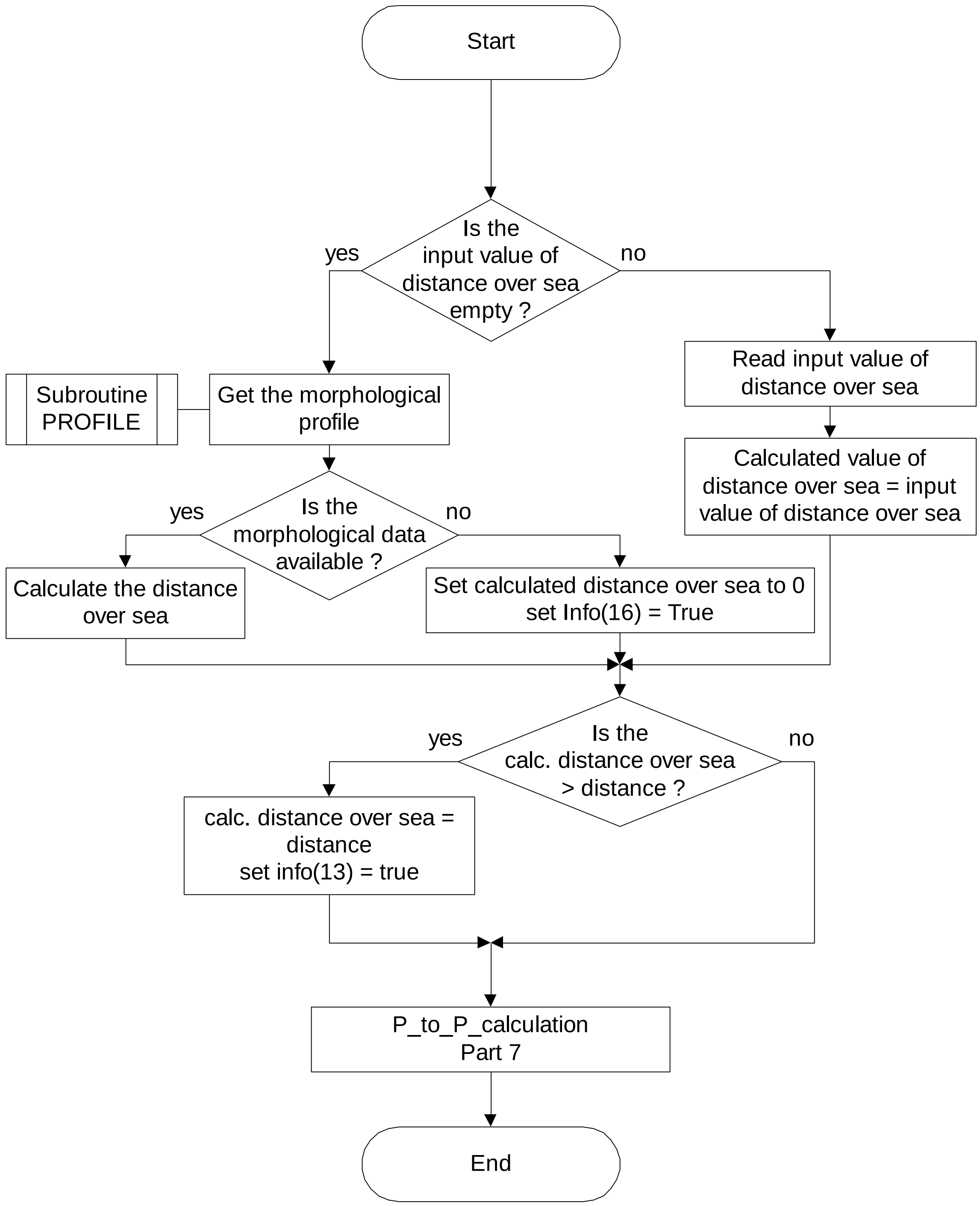
Is the calculation mode >= 0?

This subroutine is also used inside the subroutine Line_calculation. For line calculation the effective antenna height of the receiver has to be set to 10 m.

P_to_P_calculation Part 6

This process is described in the next flow chart.

Chapter 2: Subroutine P_to_P_calculation
Part 6



Subroutine P_to_P_calculation

Part 6

Is the input value of distance over sea empty?

If an input value of distance over sea is available, this value is read and used for the value of calculated distance over sea. If no input value is available, the distance over sea is calculated taking the information of the morphological database.

Get the morphological profile

The morphological profile is read with the PROFILE subroutine. This subroutine is described in chapter 5.5.

Is the morphological data available?

If the morphological data is available, the distance over sea is calculated, else it is set to 0 and the Info(16) value is set to indicate this situation.

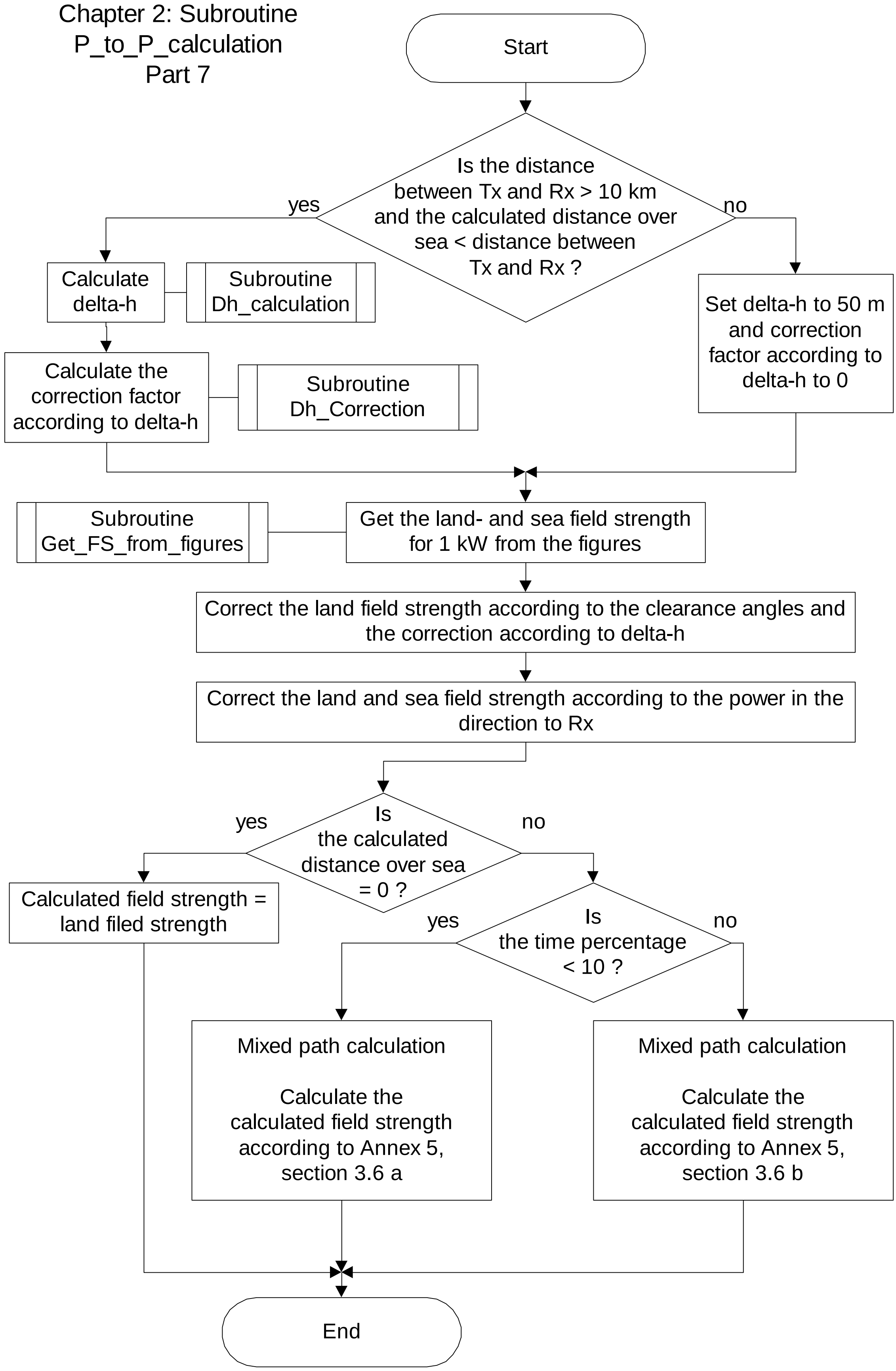
Is the calculated distance over sea > distance?

If the calculated distance over sea is greater than the distance between Tx and Rx (which may be the case if you supply an input value of distance over sea), the calculated distance is set to the distance between Tx and Rx and Info(13) is set to indicate this situation.

P_to_P_calculation Part 7

This process is described in the next flow chart.

Chapter 2: Subroutine P_to_P_calculation Part 7



Subroutine P_to_P_calculation

Part 7

Calculate delta-h

If the distance is greater than 10 km and there is a land path, than the terrain irregularity delta-h is calculated with the subroutine Dh_calculation, else delta-h is set to 50 m.
The Subroutine Dh_calculation is described in chapter 5.10.

Get the land- and sea field strength for 1 kW from the figures

The land – and sea field strength for 1 kW is calculated from the figure values. This is performed with the subroutine Get_FS_from_figures. This subroutine is described in chapter 5.12.

Correct the land field strength according to the clearance angles and the correction according to delta-h

The 1 kW land field strength is corrected with the correction factor according to the Tx terrain clearance angle, the correction factor according to the Rx terrain clearance angle and the correction factor according to the terrain irregularity.

Correct land- and sea field strength according to the power in direction to Rx

Because the land- and sea field strength calculated up till now are for 1 kW, this values need to be corrected according to the real power.

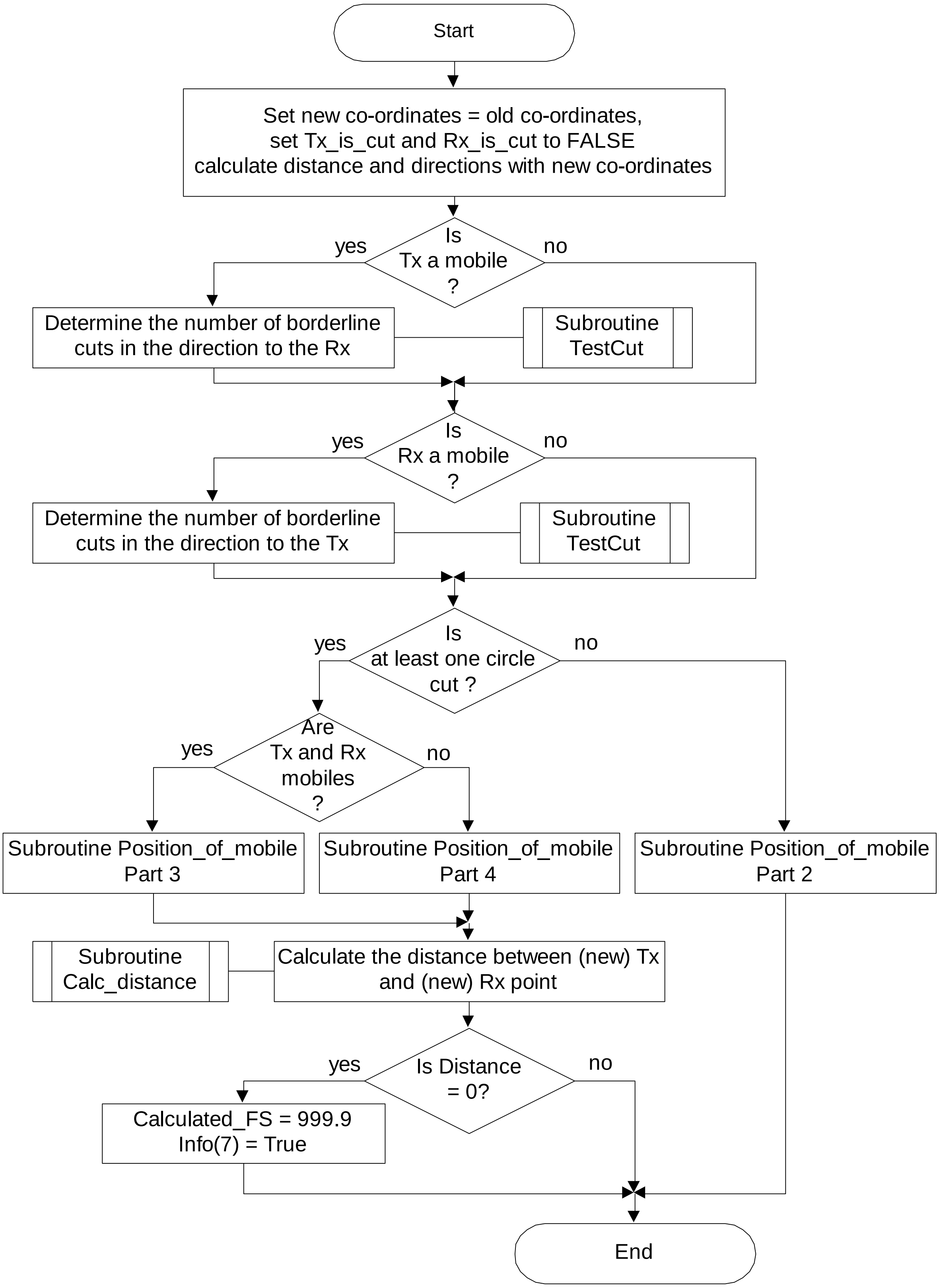
Calculated field strength = land field strength

If the whole path is land, the calculated field strength is the land field strength.

Mixed path calculation

Depending on the time percentage, the calculated field strength is calculated according to Annex 5, section 3.6a or section 3.6b.

Chapter 2.1: Subroutine Position_of_mobile
Part 1



Chapter 2.1: Subroutine Position_of_mobile

Part 1

This subroutine calculates the position of Tx or Rx for further calculation, taking into account the radius of the service areas and the border lines.

Set new co-ordinates = old co-ordinates,
set Tx_is_cut and Rx_is_cut to FALSE
calculate distance and directions with new co-ordinates

This subroutine is also used for line calculations. To ensure that for all calculations to all points of the calculation line the original Tx point together with distance and directions are used, the above mentioned settings and calculations are done.

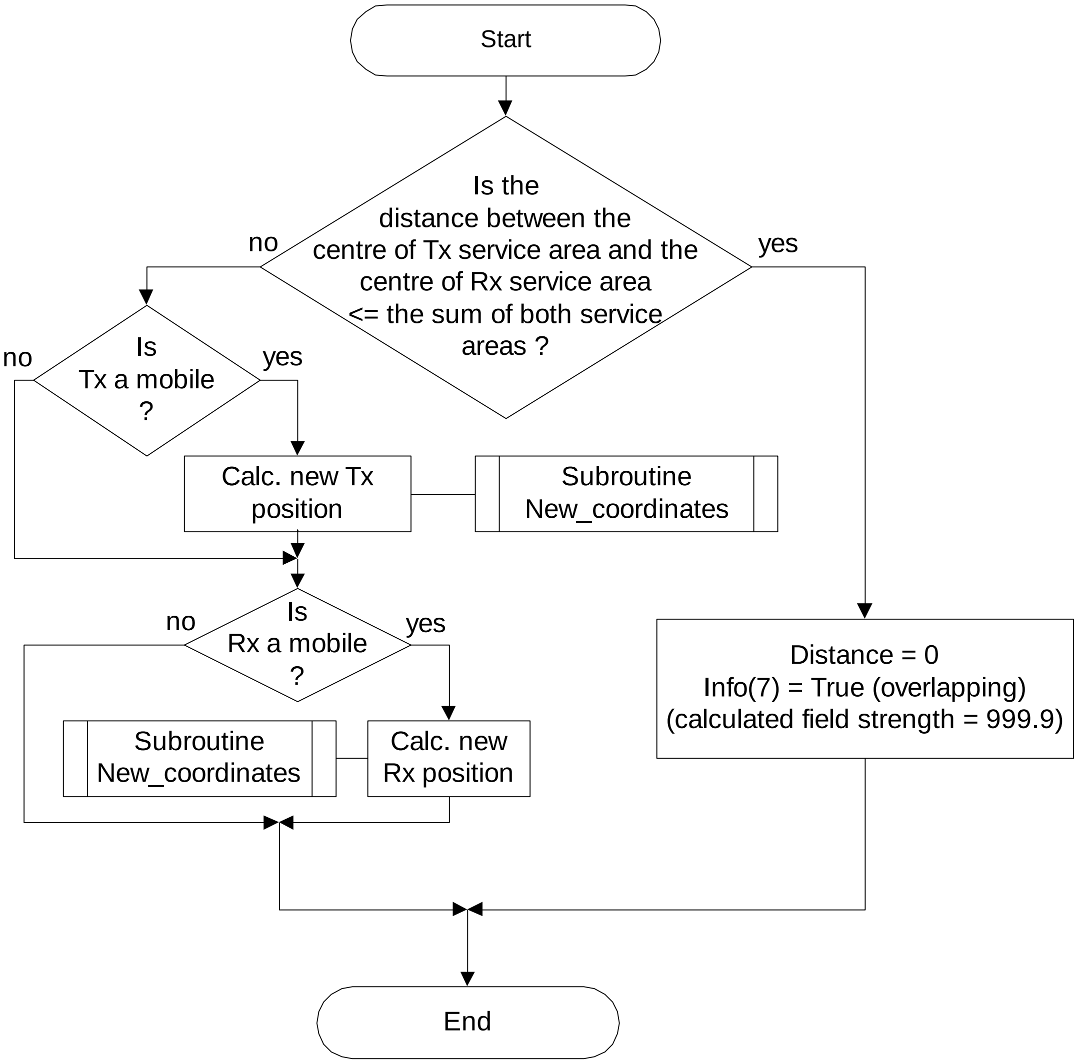
Is Tx a mobile?
Is Rx a mobile?

If Tx, Rx or both are a mobile, the number of borderline cuts is determined (see subroutine TestCut). If at least one service area is cutting the border and both stations are mobiles, the program will use the subroutine Position_of_mobile Part 3. If at least one service area is cutting the border and only one station is a mobile, the program will use the subroutine Position_of_mobile Part 4. In case no service area is cut the program will continue with the subroutine Position_of_mobile Part 2.

Calculate the distance between (new) Tx and (new) Rx point

The distance is calculated using the subroutine Calc_distance (see chapter 5.1). If this distance is 0, the calculated field strenght is set to 999.9 and info (7) is set to True to indicate the overlapping of the service areas.

Chapter 2.1: Subroutine Position_of_mobile
Part2



Subroutine Position_of_mobile

Part 2

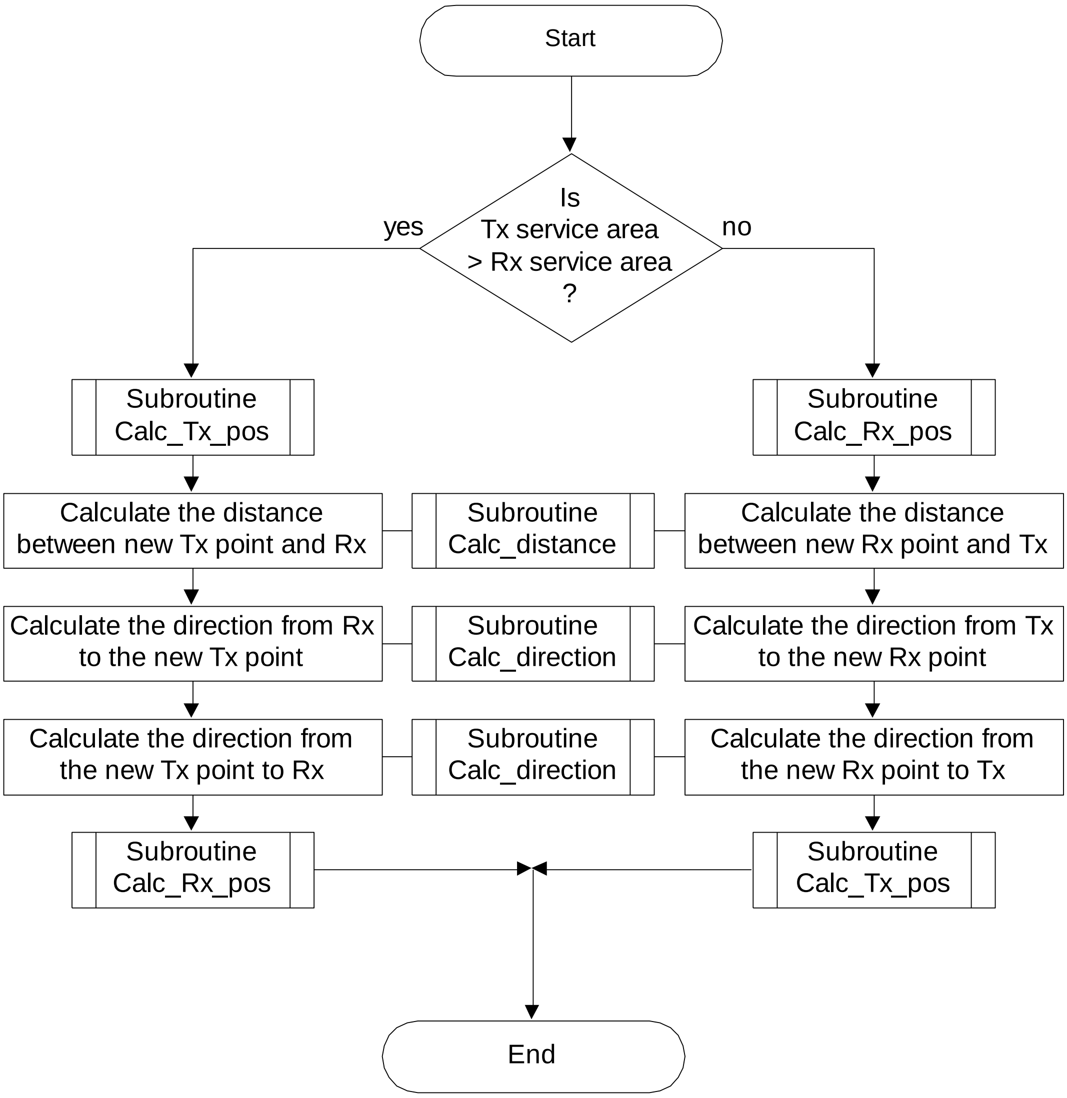
This flow-chart describes the situation when no borderline is cut.

Is the distance between the centre of Tx service area and the centre of Rx service area <= the sum of both service areas?

If the service areas of both mobiles are overlapping, or if a fixed station is located within the service area of a mobile, the distance is set to zero, an info value (7) is given and the calculated field strength is set to 999.9.

If there is no overlapping, the closest positions between both mobiles, or between a mobile and a fixed station, is calculated. This is performed by using the subroutine New_coordinates (see chapter 5.14).

Chapter 2.1: Subroutine Position_of_mobile
Part 3



Subroutine Position_of_mobile

Part 3

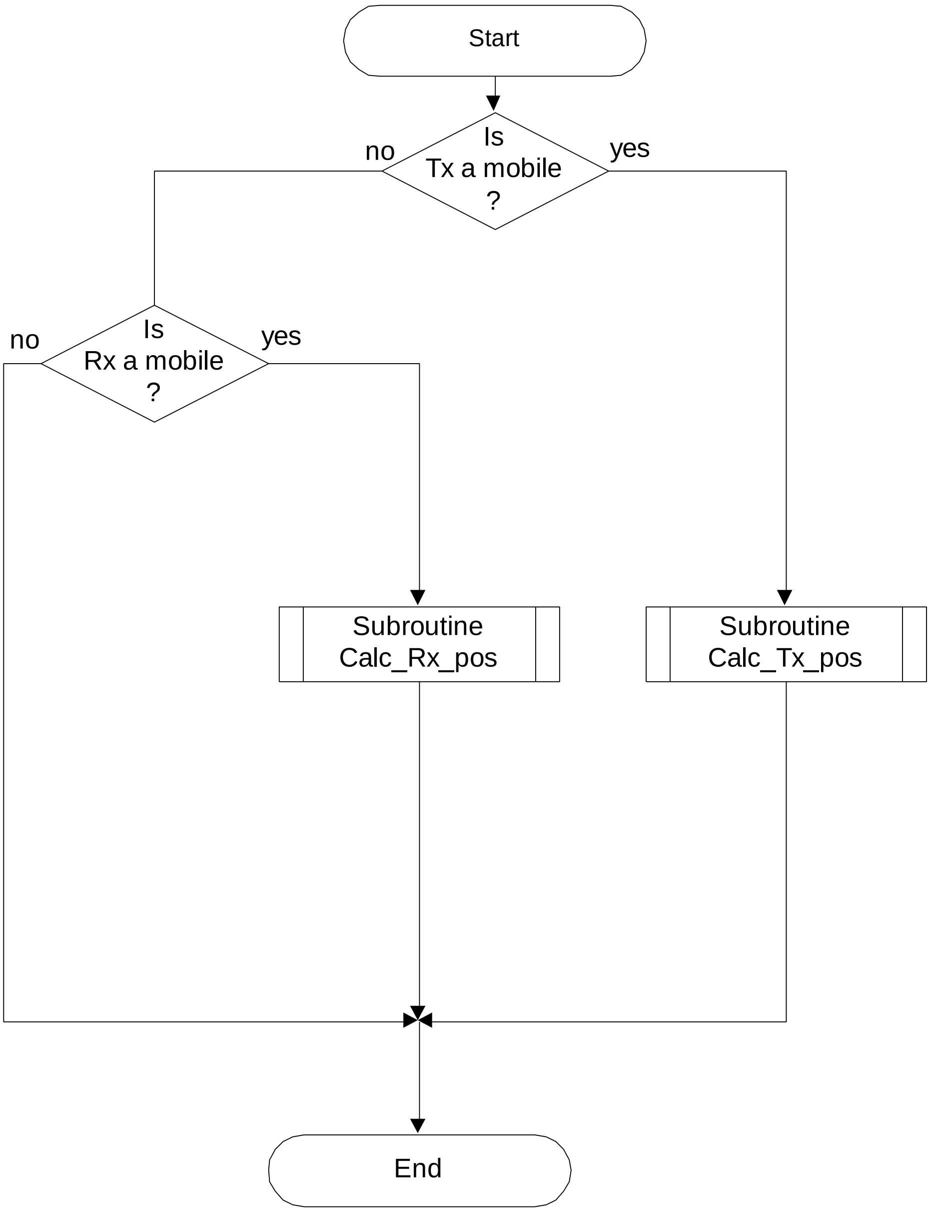
This flow-chart describes the situation when both stations are mobiles and at least one service area is cut by a borderline.

Is Tx service area > Rx service area?

For correct further calculations it is important that the station with the bigger service area is calculated first. Only in this case you can ensure that the nearest point to the other station will be found in all special borderline situations.

The new position of the stations is calculated with the subroutines Calc_Tx_pos (see chapter 2.1.3) and Calc_Rx_pos (see chapter 2.1.4). Before the new position of the other station can be calculated, the distance and the direction between the two stations needs to be recalculated.

Chapter 2.1: Subroutine Position_of_mobile
Part 4



Subroutine Position_of_mobile

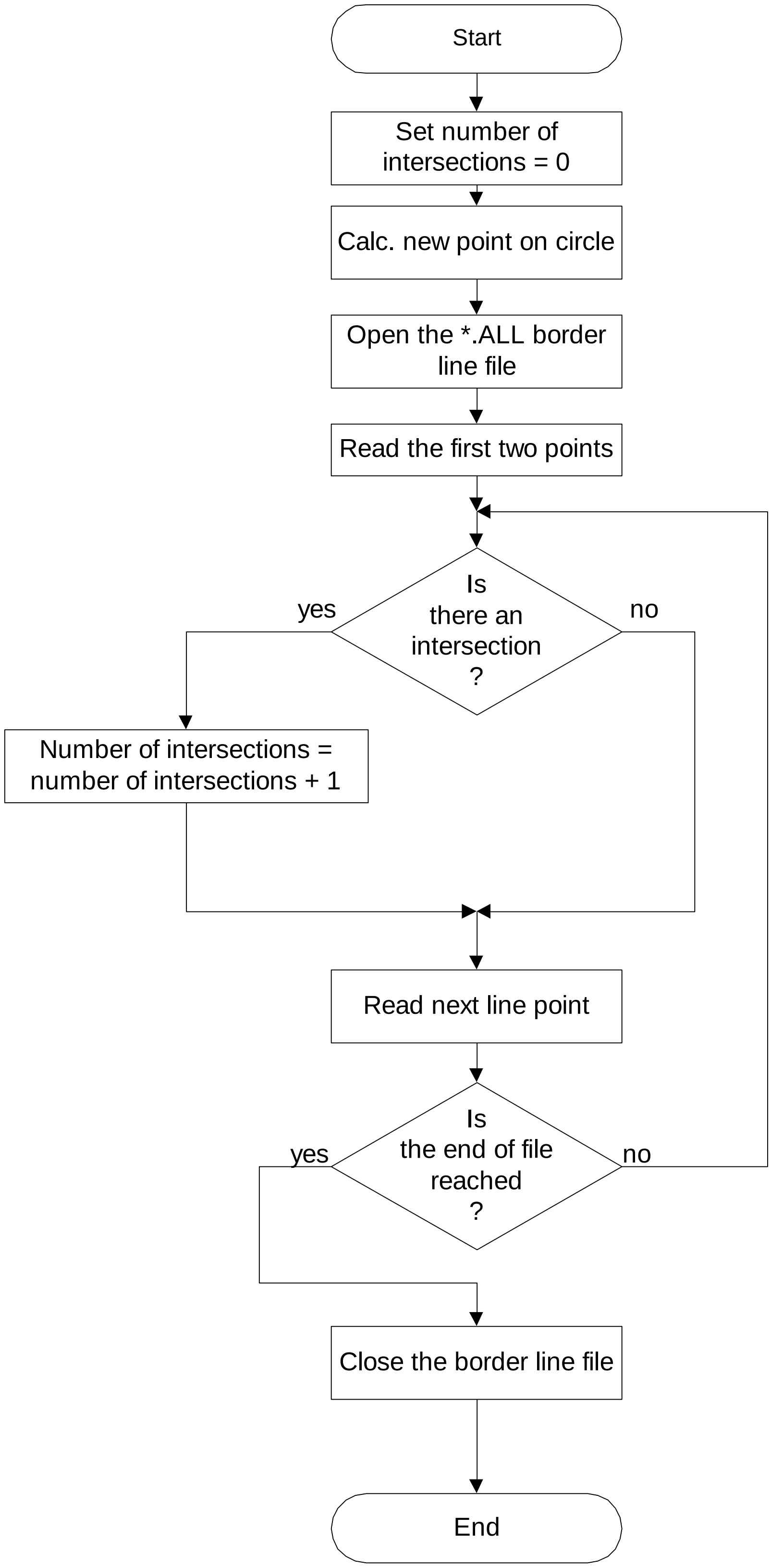
Part 4

This flow-chart describes the situation when only one station is a mobile and the service area is cut by a borderline.

Is Tx a mobile?
Is Rx a mobile?

If the Tx is a mobile, the position of the mobile is calculated with subroutine Calc_Tx_pos (see chapter 2.1.3); if Rx is a mobile, the position of the mobile is calculated with subroutine Calc_Rx_pos (see chapter 2.1.3).

Chapter 2.1.1: Subroutine TestCut



Chapter 2.1.1: Subroutine TestCut

This subroutine determinates the number of intersections between the complete borderline and the radius of the service area in the direction of the other station.

Set number of intersections = 0

Initialisation of the counter.

Calc new point on circle

The point on the edge of the service area in the direction of the other station is calculated.

*Open the *.ALL border line file*

The file containing the closed borderline of the own country is opened.

Read the first two points

The first two points of the closed borderline are read.

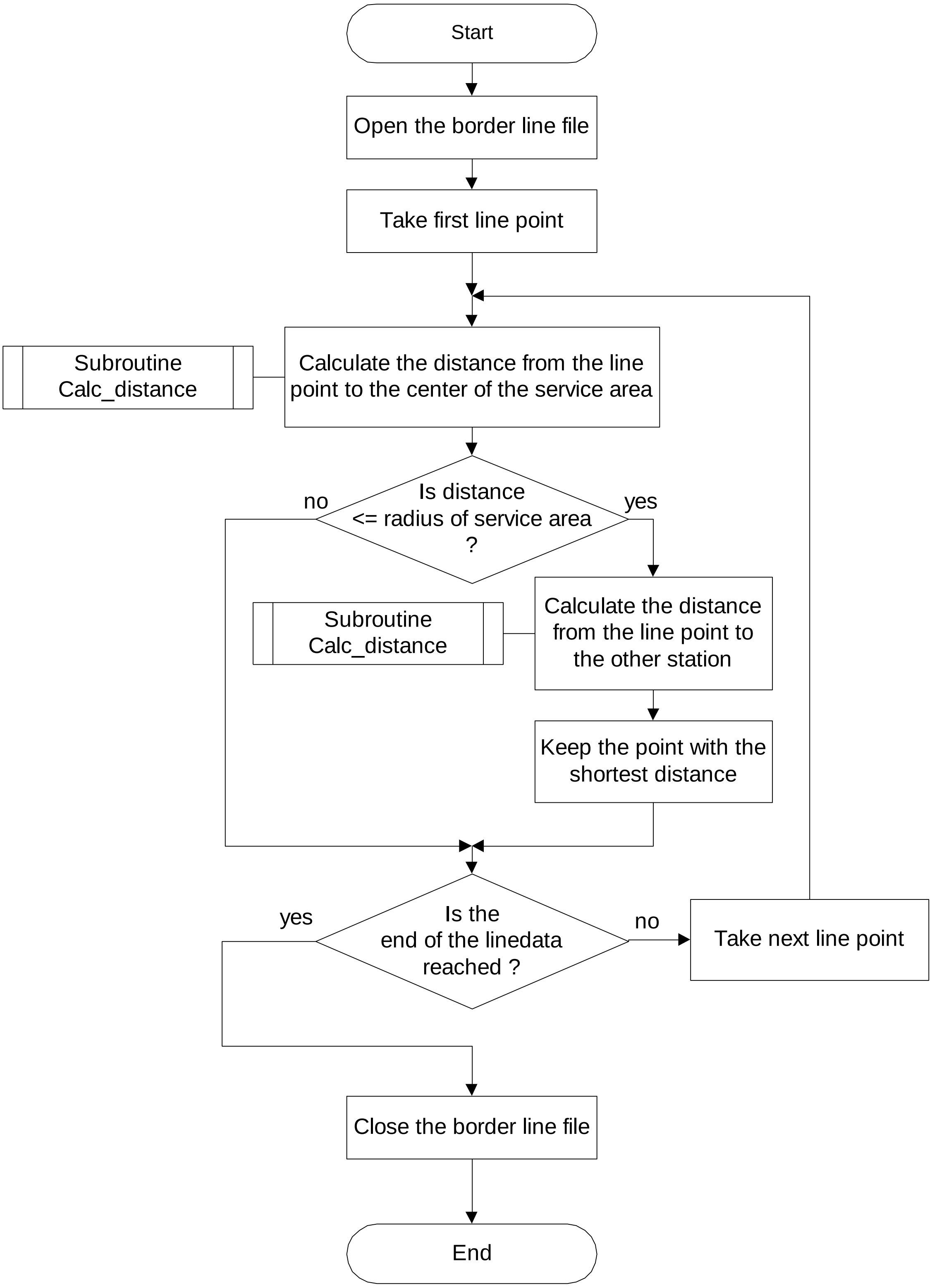
Is there an intersection?

It is tested if the radius of the service area intersects the line between the two points of the closed border line. If there is an intersection, the counter Number of intersections is incremented by 1.

Read next line point

The next point of the closed borderline is read until all points are checked.

Chapter 2.1.2: Subroutine NearestLinePoint



Chapter 2.1.2: Subroutine NearestLinePoint

Calculate the distance from the line point to the center of the service area

The distance is calculated with the subroutine Calc_distance. This subroutine is described in chapter 5.1. This proces is repeated for all points of the selected border line.
Only the points inside the service area are taken into account for further calculations.

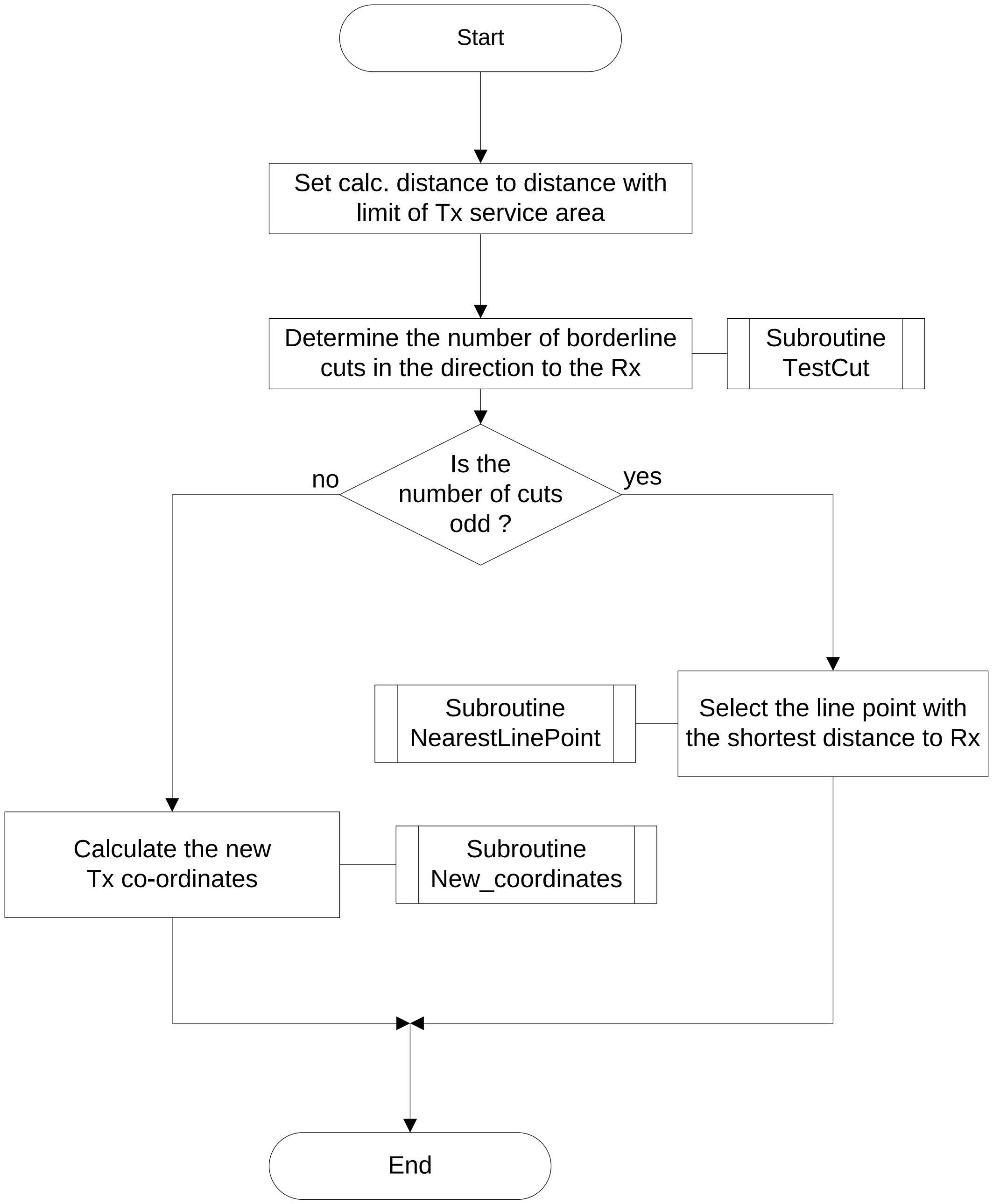
Calculate the distance from the new line point to the other station

The distance is calculated with the subroutine Calc_distance. This subroutine is described in chapter 5.1.

Keep the point with the shortest distance

The line point with the shortest distance is kept. This point is the nearest line point.

Chapter 2.1.3: Subroutine Calc_Tx_pos



Chapter 2.1.3: Subroutine Calc_Tx_pos

This subroutine calculates the position of Tx in case Tx is a mobile.

Set calc. distance to distance with limit of Tx service area

For further calculations only the points on the edge of the service area are taken into account. The part of the borderline which is inside the circle of service area of the mobile is taken into account.

Determine the number of borderline cuts in the direction to the Rx

This calculation determines the number of cuts of the borderline in the direction to Rx; if the number of cuts is even, this means that the edge of the service area of Tx in this direction is again in your own country. If the number of cuts is odd, this means that Rx is in the neighbouring country and the borderline is taken into account as part of the edge of the service area.

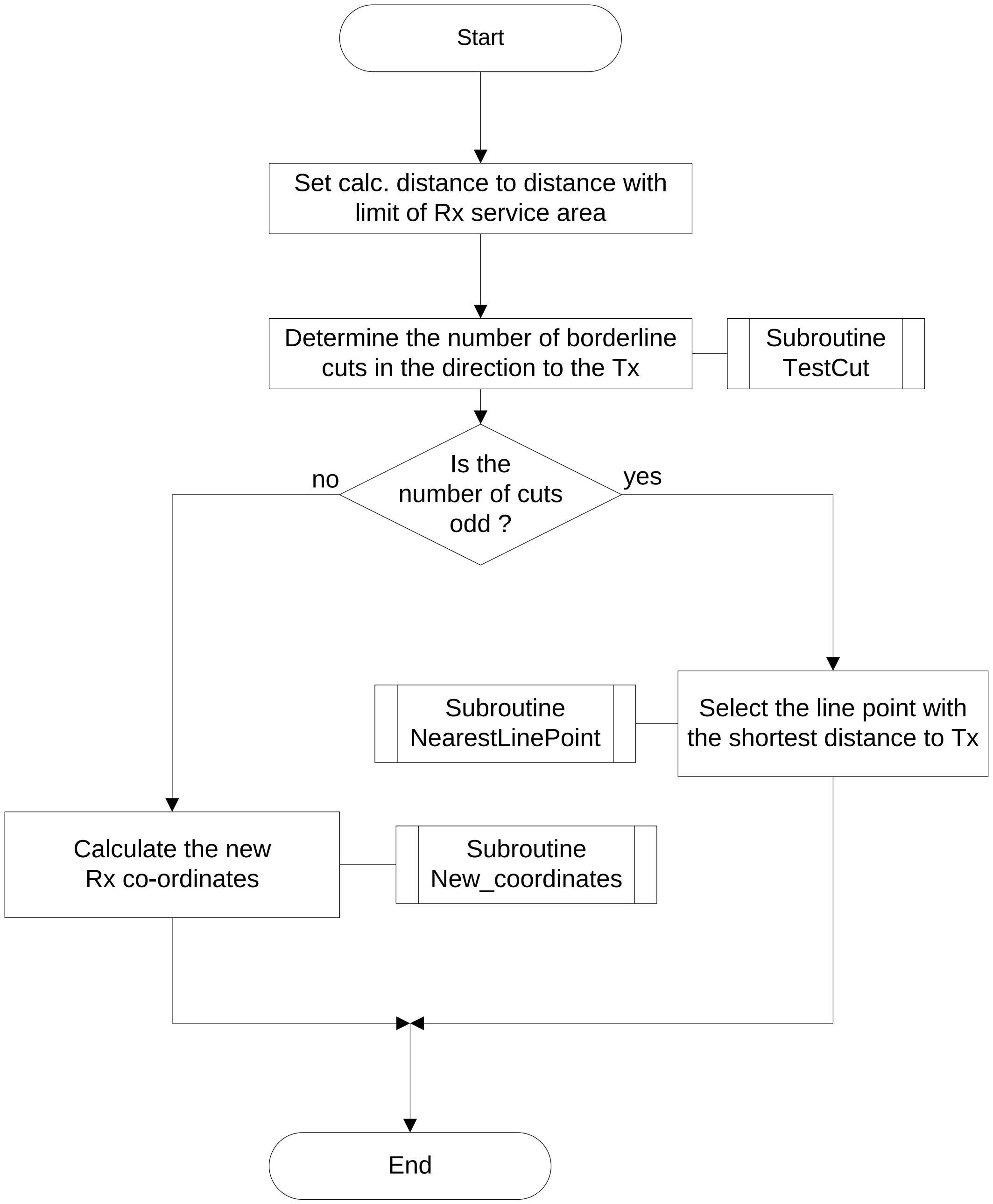
Calculate the new Tx co-ordinates

The new Tx co-ordinates are on the circle representing the edge of the service area. The co-ordinates are calculated with the subroutine New_coordinates (see chapter 5.14).

Select the line point with the shortest distance to Rx

The new Tx co-ordinates are on the part of the borderline cut by the circle representing the edge of the service area. The nearest point to Rx is selected by using the subroutine NearestLinePoint (see chapter 2.1.2).

Chapter 2.1.4: Subroutine Calc_Rx_pos



Chapter 2.1.4: Subroutine Calc_Rx_pos

This subroutine calculates the position of Rx in case Rx is a mobile.

Set calc. distance to distance with limit of Rx service area

For further calculations only the points on the edge of the service area are taken into account. The part of the borderline which is inside the circle of service area of the mobile is taken into account.

Determine the number of borderline cuts in the direction to the Tx

This calculation determines the number of cuts of the borderline in the direction to Tx; if the number of cuts is even, this means that the edge of the service area of Rx in this direction is again in your own country. If the number of cuts is odd, this means that Tx is in the neighbouring country and the borderline is taken into account as part of the edge of the service area.

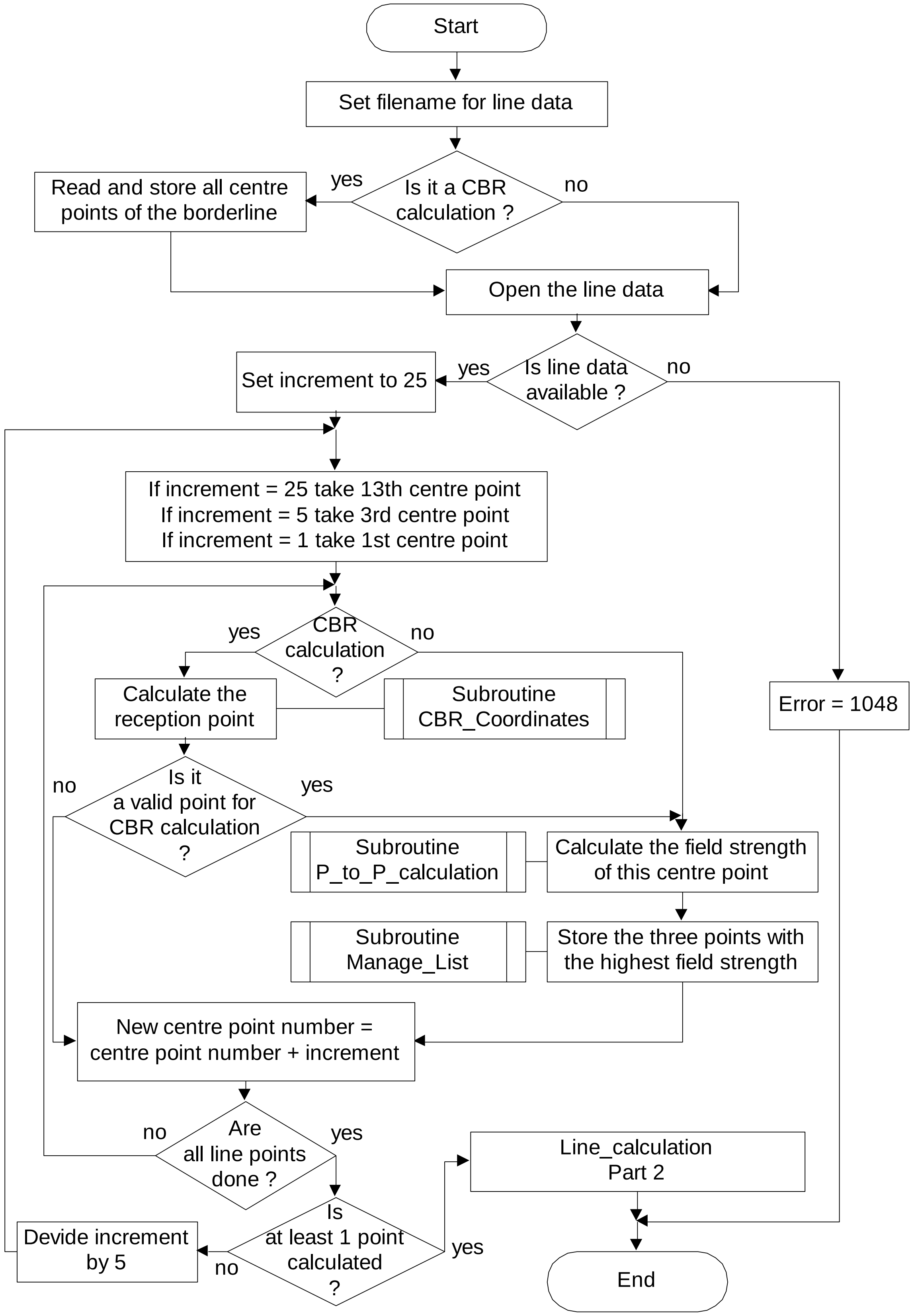
Calculate the new Rx co-ordinates

The new Rx co-ordinates are on the circle representing the edge of the service area. The co-ordinates are calculated with the subroutine New_coordinates (see chapter 5.14).

Select the line point with the shortest distance to Tx

The new Rx co-ordinates are on the part of the borderline cut by the circle representing the edge of the service area. The nearest point to Tx is selected by using the subroutine NearestLinePoint (see chapter 2.1.2).

Chapter 3: Subroutine Line_calculation
Part 1



Chapter 3: Subroutine Line_calculation

All line data are stored in records. Each record contains 10 line points following each other and an additional 11th “center point” of these 10 points.
The line calculation is performed in a iteration process to shorten the calculation process.
First, the calculation is performed to each 25th centre point of the line data, starting at the 13th centre point. The three points with the highest field strength are stored. (e.g. center points 13, 38 and 63 are stored)
Second it is calculated to each 5th centre point up to +/- 10 centre points of the previous stored points. Again the three points with the highest field strength are stored. (e.g. center points 3, 8 and 13 are stored)
Third it is calculated to each centre point up to +/- 2 centre points of the previous stored points. Again the three points with the highest field strength are stored. (e.g. center points 6, 7 and 8 are stored)
And finally each point inside the records of the stored centre points (30 points) are calculated; the point with the highest field strength is stored.

Part 1

Set filename for line data

The filename for the line data is set using the country codes of the two involved country and the distance to the borderline (see description of the line data in chapter 8).

Read and store all centre points of the borderline

In case of a cross-border range calculation, all centre points of the closed borderline of the whole affected country (xxx.ALL file) are read and stored for the test if a borderline point is cut or not (CBR calculations are only performed if a neighbouring country is affected).

Open the line data

For all calculations the appropriate borderline, the CBR line or the X-km line is opened. In case the data is not available the program terminates with error code 1048.

Calculate reception point

The reception point for a CBR calculation is calculated using subroutine CBR_Coordinates. This subroutine is described in chapter 3.1.

Is it a valid point for CBR calculation?

One outcome of the subroutine CBR_Cooordinates (see 3.1) is the information, whether it is a valid point or not. Valid points are those points where at least one point of the propagation path is in the affected country.

Calculate the field strength of this center point

This calculation is performed using the subroutine P_to_P_calculation that is described in chapter 2.

Store the three points with the highest field strength

The three points with the highest field strength are stored using subroutine Manage_List that is described in chapter 3.3.

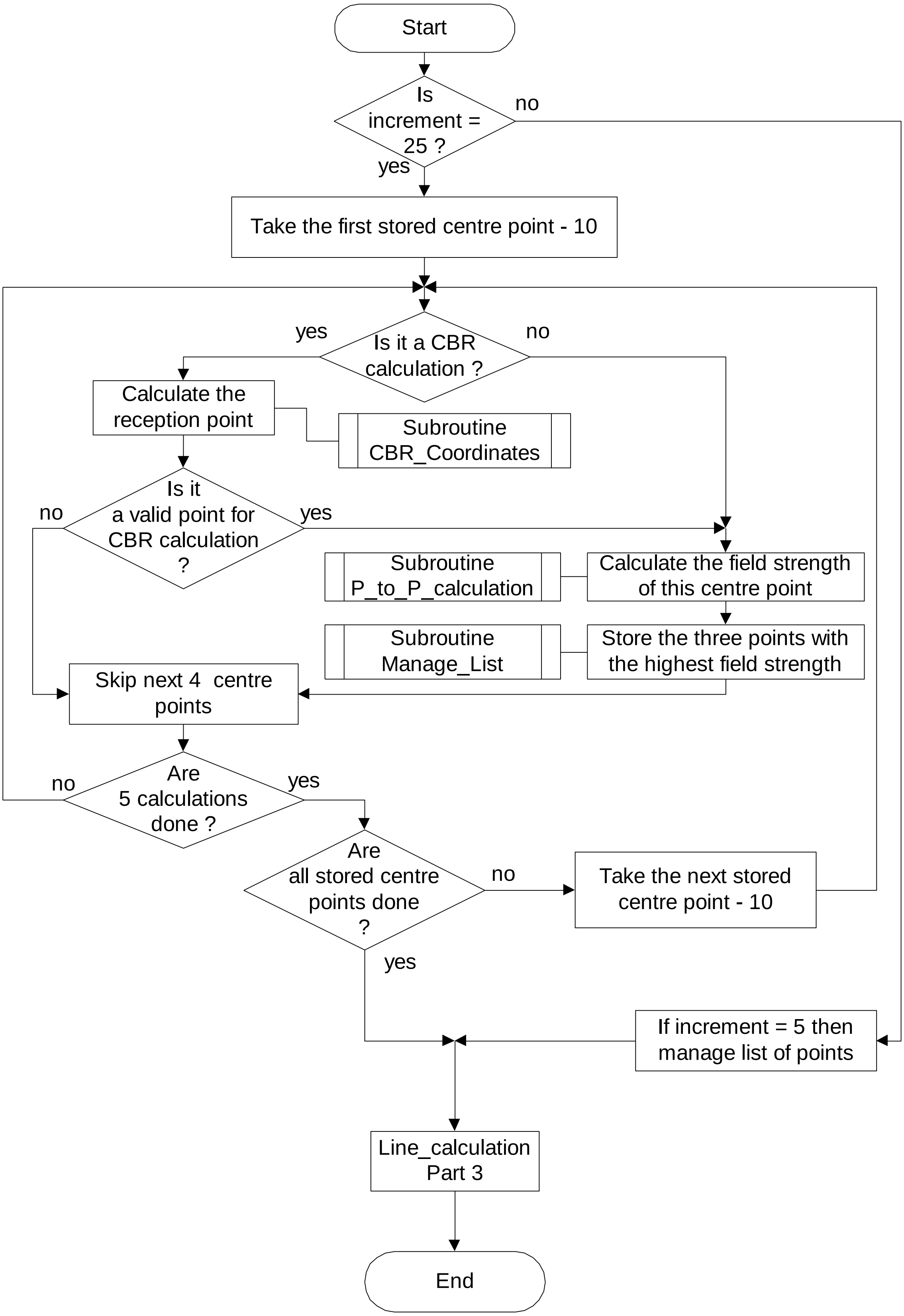
Is at least 1 point calculated?

For small co-ordination line files it may happen that no valid point is found with the highest increment. In this case the increment is decreased until at least one point is found.

Line_calculation Part 2

This process is described in the next flow chart.

Chapter 3: Subroutine Line_calculation
Part 2



Subroutine Line_calculation

Part 2

Is increment = 25?

If, in the case of small co-ordination line files, the increment already is decreased to 5 or 1, no new iteration with increment 5 is needed, only the list of stored points has to be managed.

Take the first/next stored center point

The stored center points of the previous iteration level are taken into account.

Calculate reception point

The reception point for a CBR calculation is calculated using subroutine CBR_Coordinates. This subroutine is described in chapter 3.1.

Is it a valid point for CBR calculation?

One outcome of the subroutine CBR_Cooordinates (see 3.1) is the information, whether it is a valid point or not. Valid points are those points, where at least one point of the propagation path is in the affected country.

Calculate the field strength of this center point

This calculation is performed using the subroutine P_to_P_calculation that is described in chapter 2.

Store the three points with the highest field strength

The three points with the highest field strength are stored in a new set for the next iteration level, using subroutine Manage_List that is described in chapter 3.3.

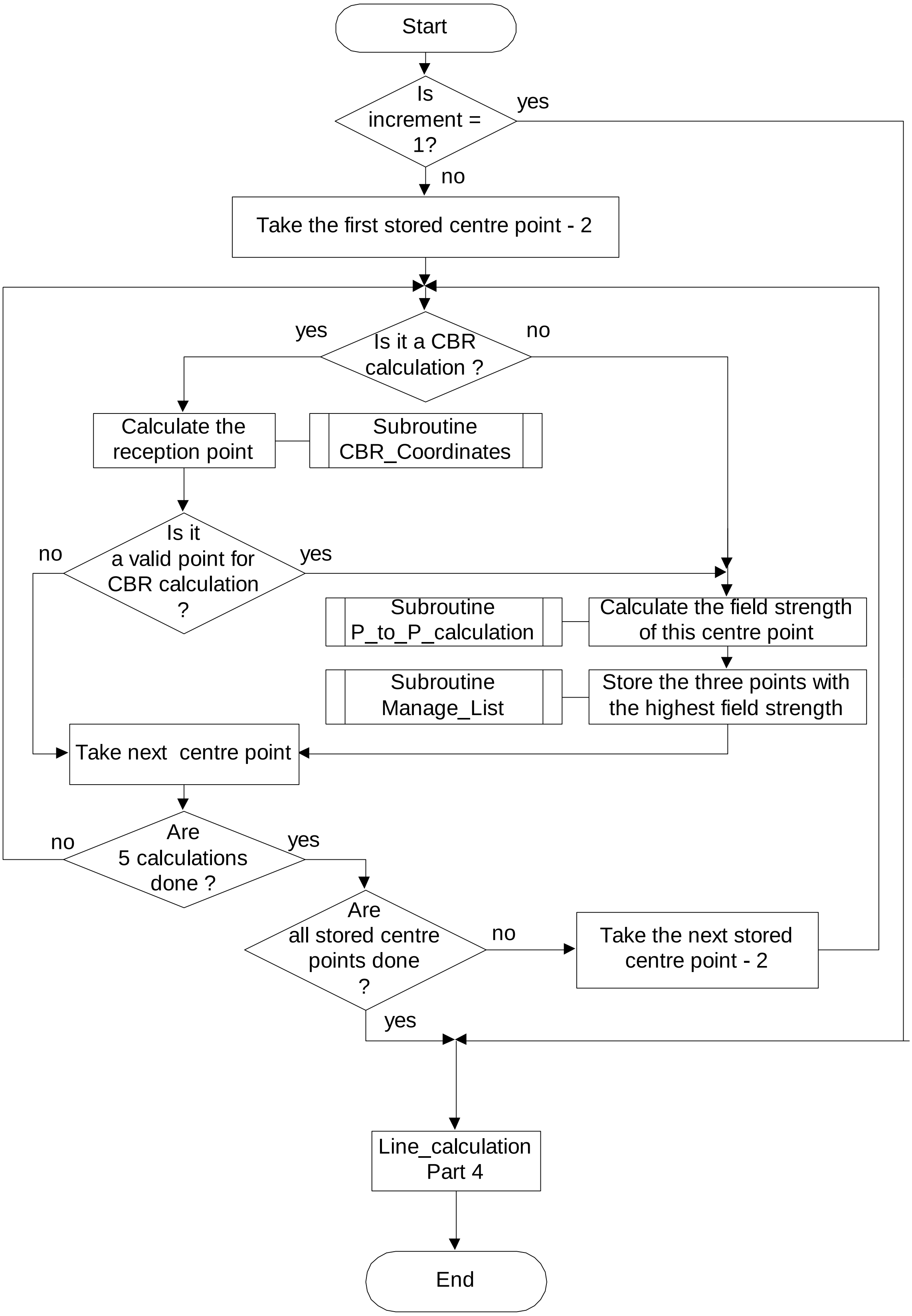
If increment = 5 then manage list of points

For the whole process of line calculations, two lists of record numbers and field strenghts are available. List 1 is used for the first and third iteration process. List 2 is used for the second iteration process. If in the first process the increment is already decreased to 5 (normally done in the second iteration process), the content of list 1 is copied to list 2. If the increment is already 1, the list 1 is the final list.

Line_calculation Part 3

This process is described in the next flow chart.

Chapter 3: Subroutine Line_calculation
Part 3



Subroutine Line_calculation

Part 3

Is increment = 1?

If the increment is already set to 1 in part 1 of this calculation, this part of the calculation process is skipped.

Calculate reception point

The reception point for a CBR calculation is calculated using subroutine CBR_Coordinates. This subroutine is described in chapter 3.1.

Is it a valid point for CBR calculation?

One outcome of the subroutine CBR_Cooordinates (see 3.1) is the information, whether it is a valid point or not. Valid points are those points, where at least one point of the propagation path is in the affected country..

Calculate the field strength of this point

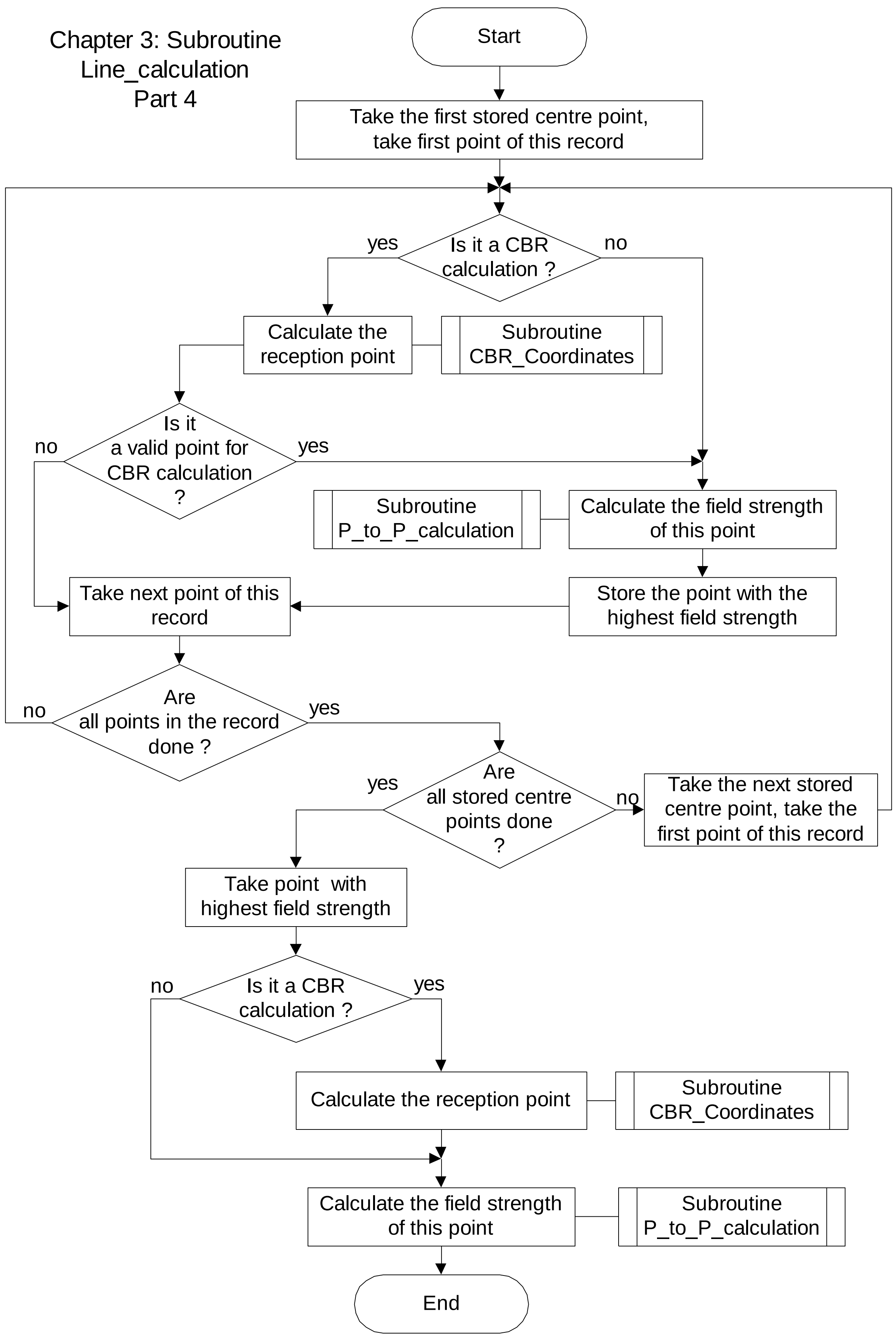
This calculation is performed using the subroutine P_to_P_calculation that is described in chapter 2.

Store the three points with the highest field strength

The three points with the highest field strength are stored using subroutine Manage_List that is described in chapter 3.3.

Line_calculation Part 4

This process is described in the next flow chart.


Chapter 3: Subroutine
Line_calculation
Part 4
Start
Take the first stored centre point, take first point of this record
Is it a CBR calculation ?
yes
no
Calculate the reception point
Subroutine CBR_Coordinates
Is it a valid point for CBR calculation ?
no
yes
Subroutine P_to_P_calculation
Calculate the field strength of this point
Take next point of this record
Store the point with the highest field strength
Are all points in the record done ?
no
yes
Are all stored centre points done ?
yes
no
Take the next stored centre point, take the first point of this record
Take point with highest field strength
Is it a CBR calculation ?
no
yes
Calculate the reception point
Subroutine CBR_Coordinates
Calculate the field strength of this point
Subroutine P_to_P_calculation
End

Subroutine Line_calculation

Part 4

Calculate reception point

The reception point for a CBR calculation is calculated using subroutine CBR_Coordinates. This subroutine is described in chapter 3.1.

Is it a valid point for CBR calculation?

One outcome of the subroutine CBR_Cooordinates (see 3.1) is the information, whether it is a valid point or not. Valid points are those points, where at least one point of the propagation path is in the affected country..

Calculate the field strength of this point

This calculation is performed using the subroutine P_to_P_calculation that is described in chapter 2.

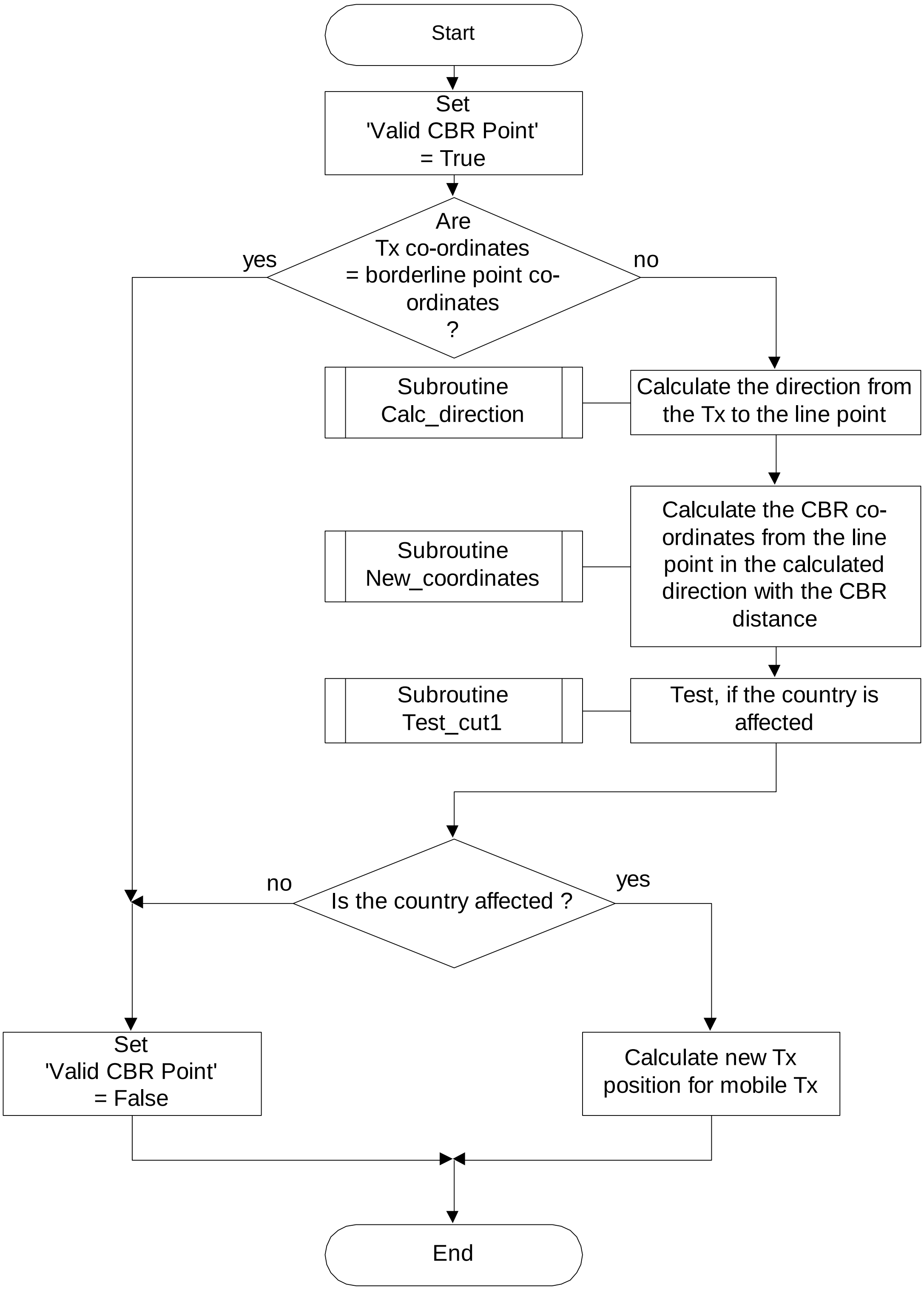
Store the point with the highest field strength

Only the point with the highest field strength is stored.

Take point with highest field strenght

After the 30 calculations are done, the calculation to the point with the highest field strenght has to be redone to get the correct output values.

Chapter 3.1: Subroutine CBR_Coordinates



Chapter 3.1: Subroutine CBR_Coordinates

Calculate the direction from the Tx to the line point

The direction is calculated with the subroutine Calc_direction. This subroutine is described in chapter 5.2.

Are Tx co-ordinates = borderline point co-ordinates?

If the transmitter is located on a borderline point, this point is not taken into a count for this calculation. For the mobile these co-ordinates represent the centre of service area, not the position of the mobile itself. The position of the mobile is calculated at the end of this subroutine.

Calculate the CBR co-ordinates from the line point in the calculated direction with the CBR distance.

The new CBR co-ordinates are calculated with the subroutine New_coordinates. This subroutine is described in chapter 5.14

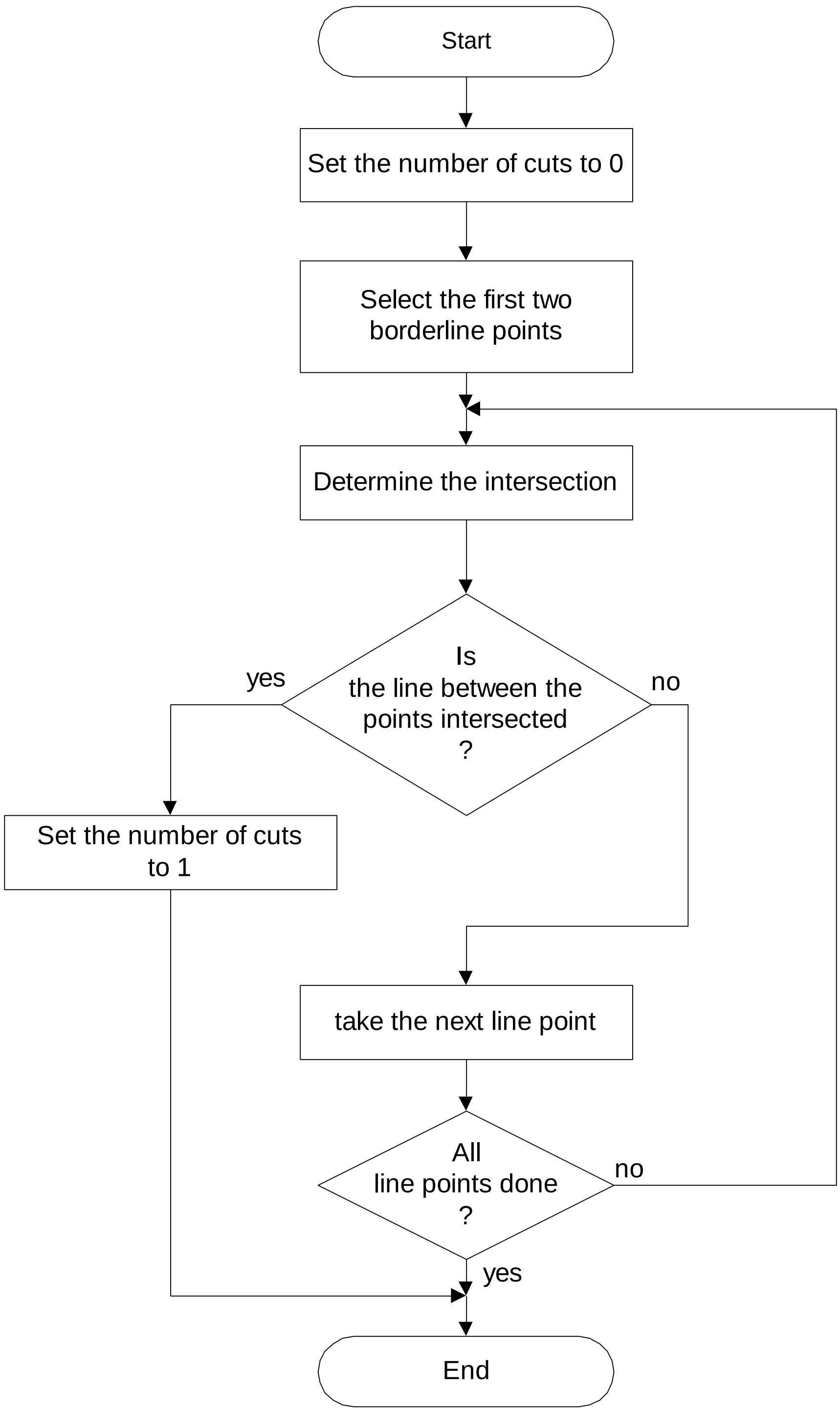
Test, if the country is affected

This test is done with the subroutine Test_cut1 which is described in chapter 3.2.

Is the country affected?

If the propagation path crosses the borderline of a country (at least one cut), then the country is affected.

Chapter 3.2: Subroutine Test_cut1



Chapter 3.2: Subroutine Test_cut1

This subroutine only determines if the closed borderline is cut. The number of cuts is not important.
This subroutine uses only the centre points of the borderline. These points are already stored in the subroutine Line_calculation chapter 3 part 1.

Select the first two line points

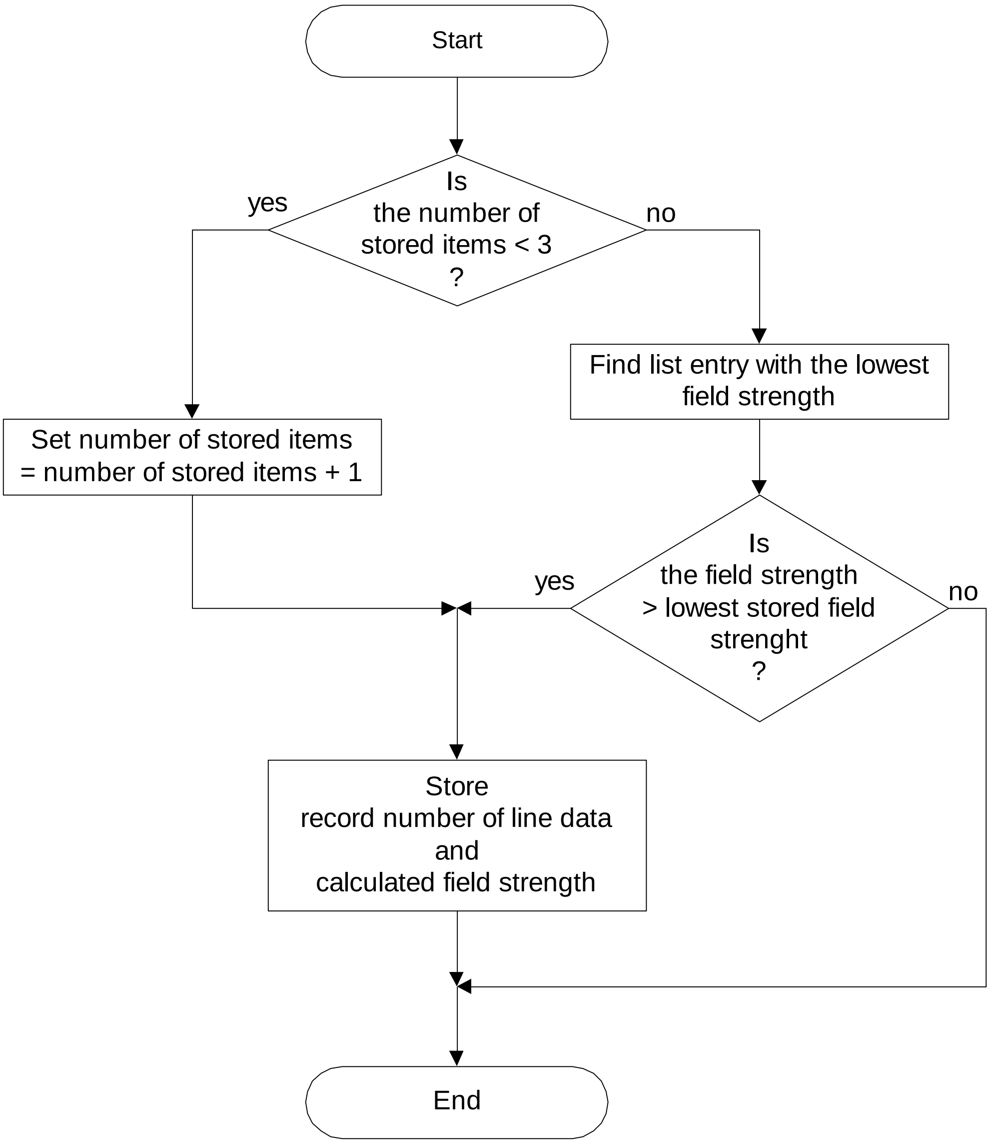
This process starts by selecting the first two borderline centre points.

Is the line between the points intersected?

If the line between the two selected centre points is intersected by the propagation path, the number of cuts is set to one and the process terminates because it is enough if only one point of the country is affected. In this case, there is no need to test additional points.

If the line is not intersected, the next line point is taken and the intersection of the line between the new point and the ending point of the previous test is tested and so on until all line points are done.

Chapter 3.3: Subroutine Manage_List



Chapter 3.3: Subroutine Manage_List

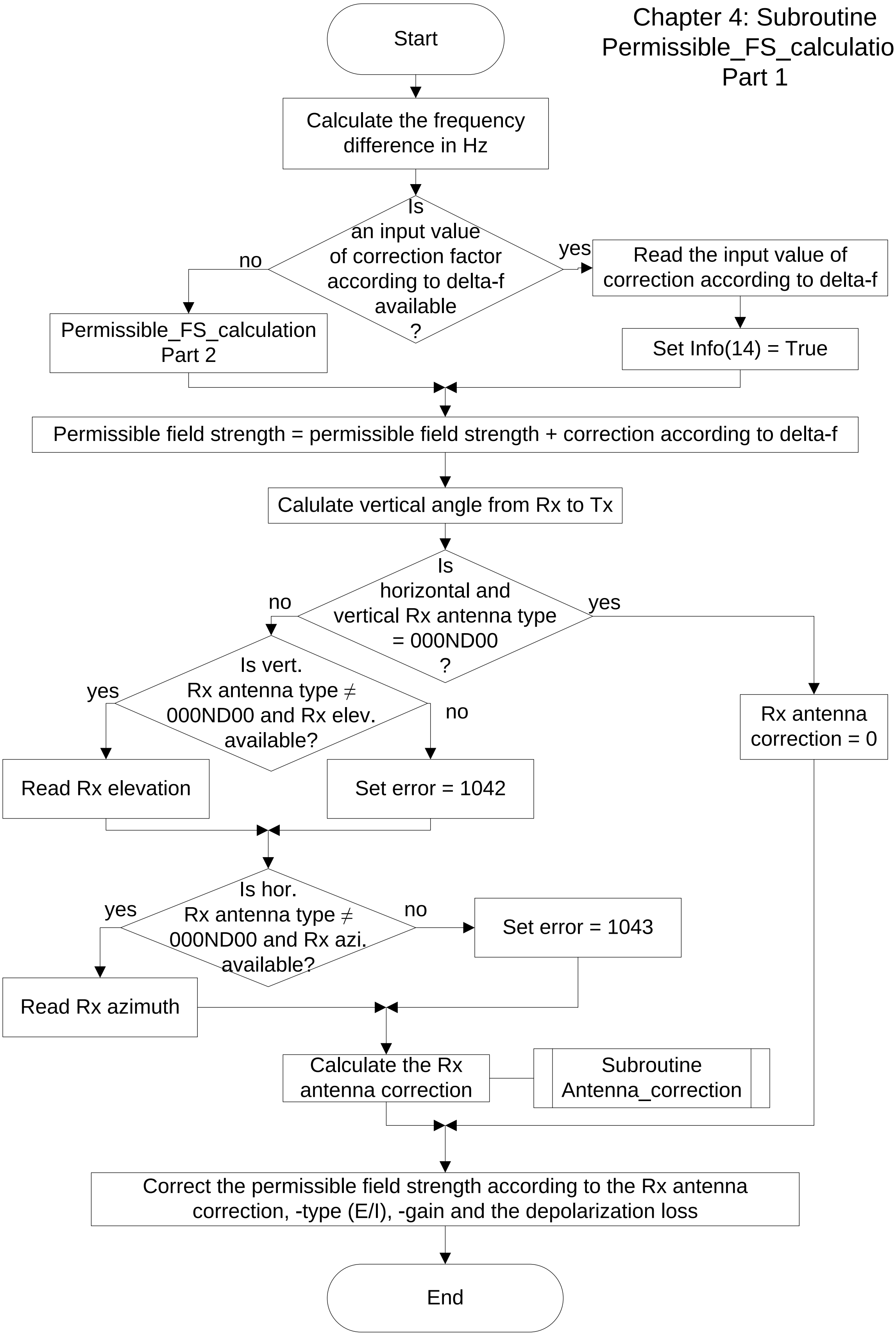
For the whole process of line calculations, two lists of record numbers and field strenghts are available. List 1 is used for the first and third iteration process. List 2 is used for the second iteration process.

Is number of stored items < 3?

If the number of stored items is less than 3, then the number of stored items is increased and the record number of the co-ordinates of the new calculated point and the calculated field strength are stored in this list place.

If the number of stored records is 3 (all list places are occupied), then the entry with the lowest field strength is found and if the field strength is greater than the stored field strength this entry is overwritten with the new values.

Chapter 4: Subroutine Permissible_FS_calculation Part 1



Chapter 4: Subroutine Permissible_FS_calculation

Part 1

In part 1 of this subroutine the permissible field strenght is corrected according to the frequency difference, the Rx antenna diagram and antenna gain and the depolarization loss.

Calculate the frequency difference in Hz

The absolute difference between Tx and Rx frequency is calculated in Hz.

Is an input value of correction factor according to delta-f available?

If an input value of correction factor according to delta-f is available, this value is read and used and Info(14) value is set to indicate this situation.
If no input value is available, the correction factor according to delta-f is calculated.

Is frequency difference = 0?

If the frequency difference is 0, the correction factor according to delta-f is set to 0, else it is calculated.

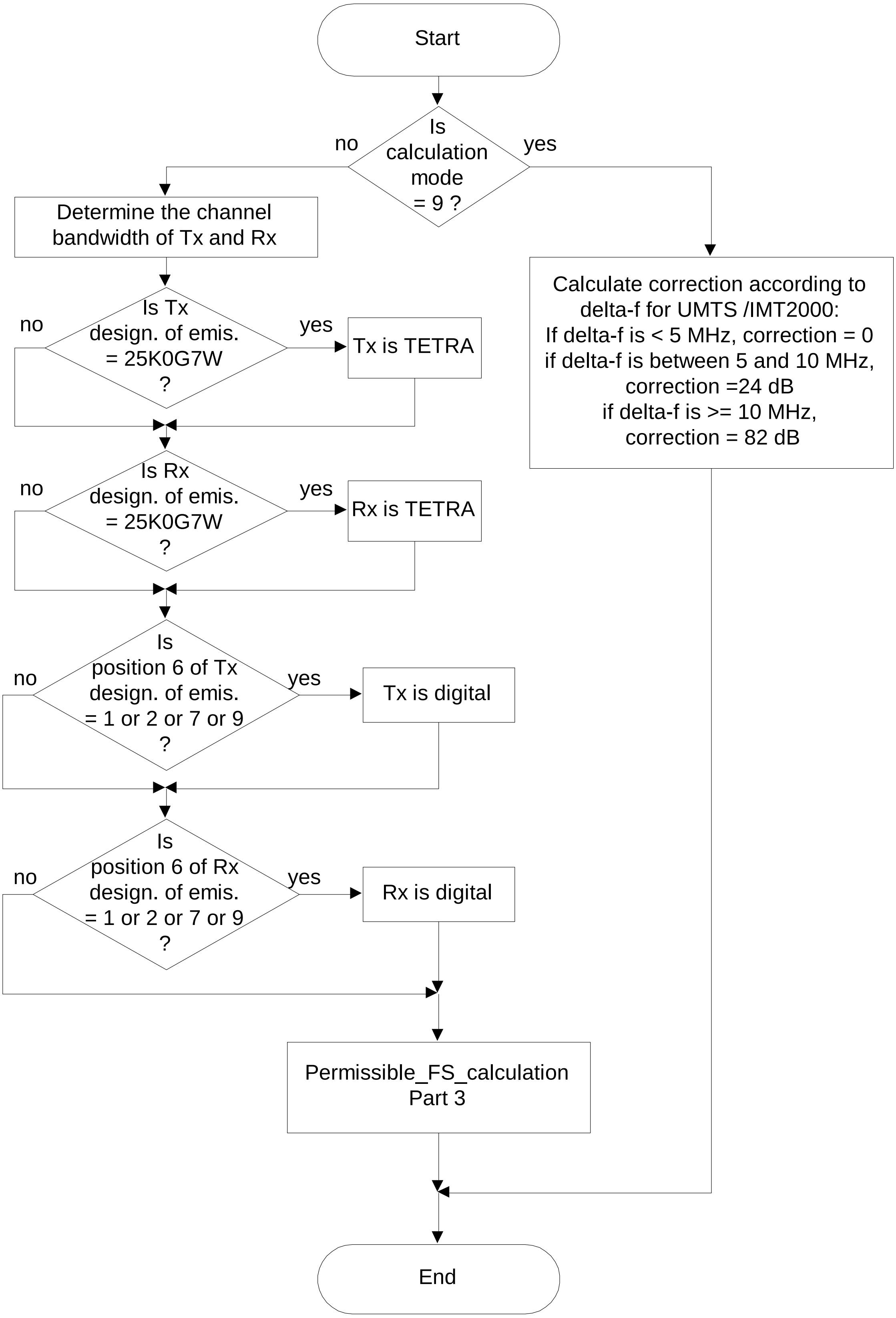
Permissible_FS_calculation Part2

This process is described in the next flow chart.

Calculate the Rx antenna correction

This process is done with the subroutine Antenna_correction. This subroutine is described in chapter 5.7.

Chapter 4: Subroutine Permissible_FS_calculation
Part 2



Subroutine Permissible_FS_calculation

Part 2

This part 2 of the subroutine Permissible_FS_calculation determines the correction factor according to Δf for UMTS/IMT 2000 and determines if transmitter and receiver are TETRA or digital systems.

Determine the occupied bandwidth of Tx and Rx

The occupied bandwidth is determined by the first four characters of the designation of emission. It is not the channel spacing!

Is Tx (Rx) design. of emis. = 25K0G7W?

Only if the 7 first characters of the designation of emission of Tx and / or Rx are equal to '25K0G7W' then the Tx and / or Rx is a TETRA system.

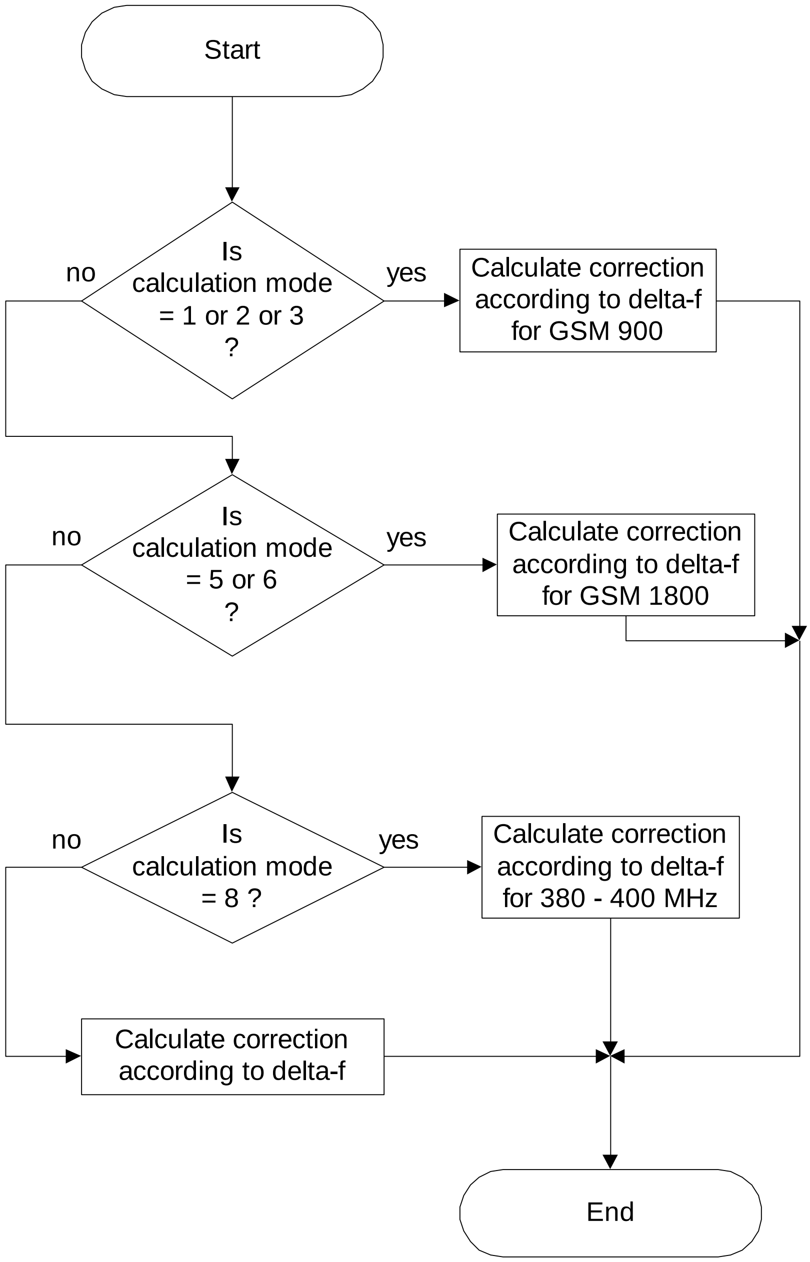
Is position 6 of Tx (Rx) design. of emis. = 1 or 2 or 7 or 9?

Only if the 6th character of the designation of emission of Tx and / or Rx is equal to 1 or 2 or 7 or 9 then the Tx and / or Rx are a digital system. (Needed for narrow band systems in the band 380/400 MHz and for digital wideband systems).

Permissible_FS_calculation Part3

This process is described in the next flow chart.

Chapter 4: Subroutine Permissible_FS_calculation
Part 3



Subroutine Permissible_FS_calculation

Part 3

This part 3 of the subroutine Permissible_FS_calculation selects the correction factor according to Δf depending on the different modes.

Calculate correction according to delta-f for GSM900

If the calculation mode is 1 or 2 or 3, then the correction according to delta-f is calculated for GSM900. This process is described in chapter 4.2.

Calculate correction according to delta-f for GSM1800

If the calculation mode is 5 or 6, then the correction according to delta-f is calculated for GSM1800. This process is described in chapter 4.3.

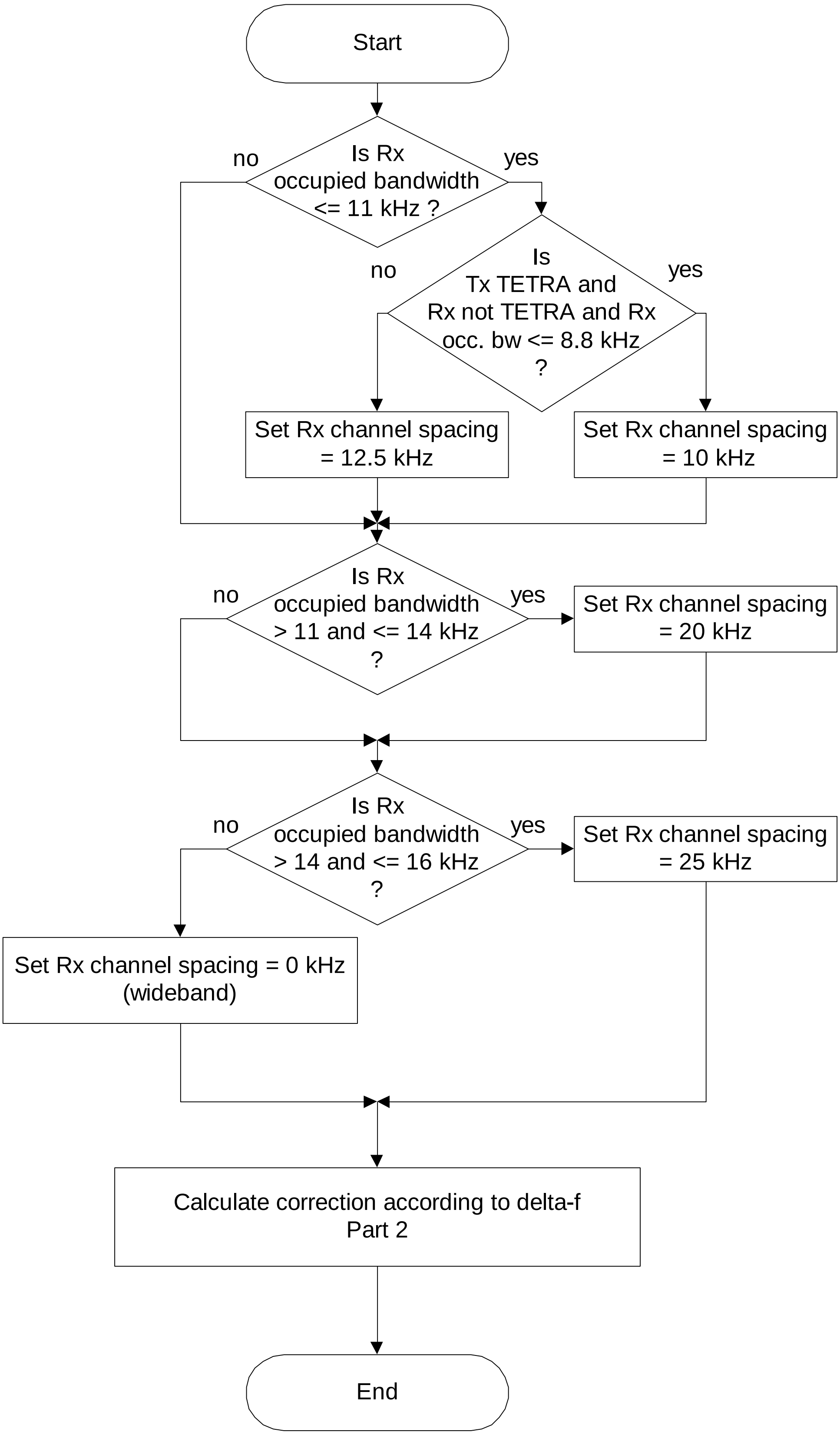
Calculate correction according to delta-f for 380 – 400 MHz

If the calculation mode is 8, then the correction according to delta-f is calculated for 380 – 400 MHz. This process is described in chapter 4.4.

Calculate correction according to delta-f for normal HCM Agreement

If the calculation mode is 0 or 4 or 7, then the correction according to delta-f is calculated for the normal HCM Agreement. This process is described in chapter 4.1.

Chapter 4.1: Calculate correction according to delta-f
Part 1



Chapter 4.1: Calculate correction according to delta-f for normal HCM Agreement

Part 1

Here, the subroutine determines which channel spacing for Rx has to be used.

In this flow chart, the Rx channel spacing is set according to the occupied bandwidth.

If the Rx occupied bandwidth is less than or equal to 11 kHz, then the Rx channel spacing is set to 12.5 kHz.
If the Rx occupied bandwidth is between 11 and 14 kHz, then the Rx channel spacing is set to 20 kHz.
If the Rx occupied bandwidth is greater than 14 kHz, then the Rx channel spacing is set to 25 kHz.

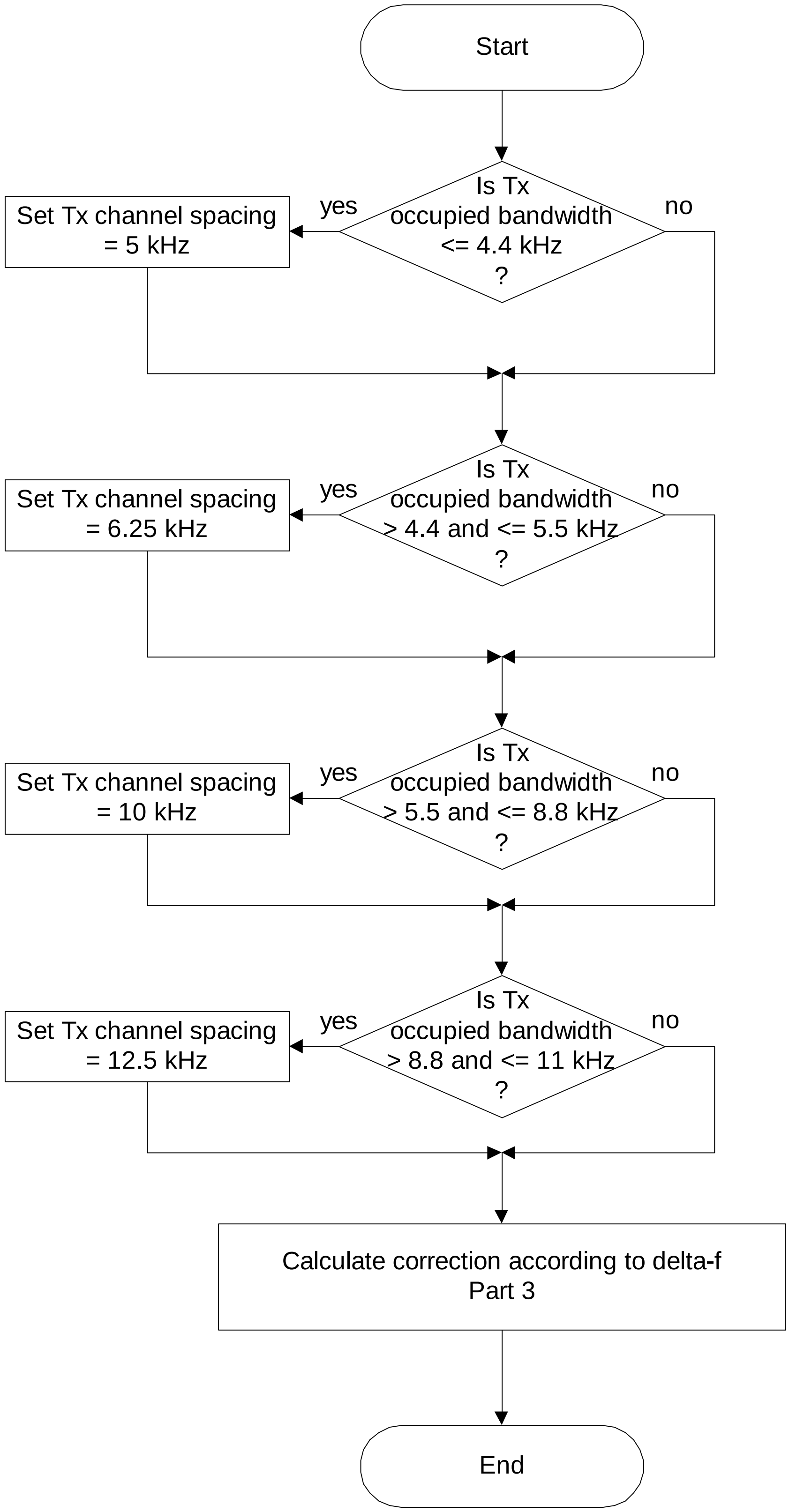
If the Tx is TETRA and the Rx occupied bandwidth is less than or equal to 8.8 kHz, then the Rx channel spacing is set to 10 kHz.

The bandwith is set to 0 to indicate that the receiver is belonging to a wideband system.

Calculate correction according to delta-f for normal HCM Agreement Part 2

This process is described in the next flow chart.

Chapter 4.1: Calculate correction according to delta-f
Part 2



Calculate correction according to delta-f for normal HCM Agreement

Part 2

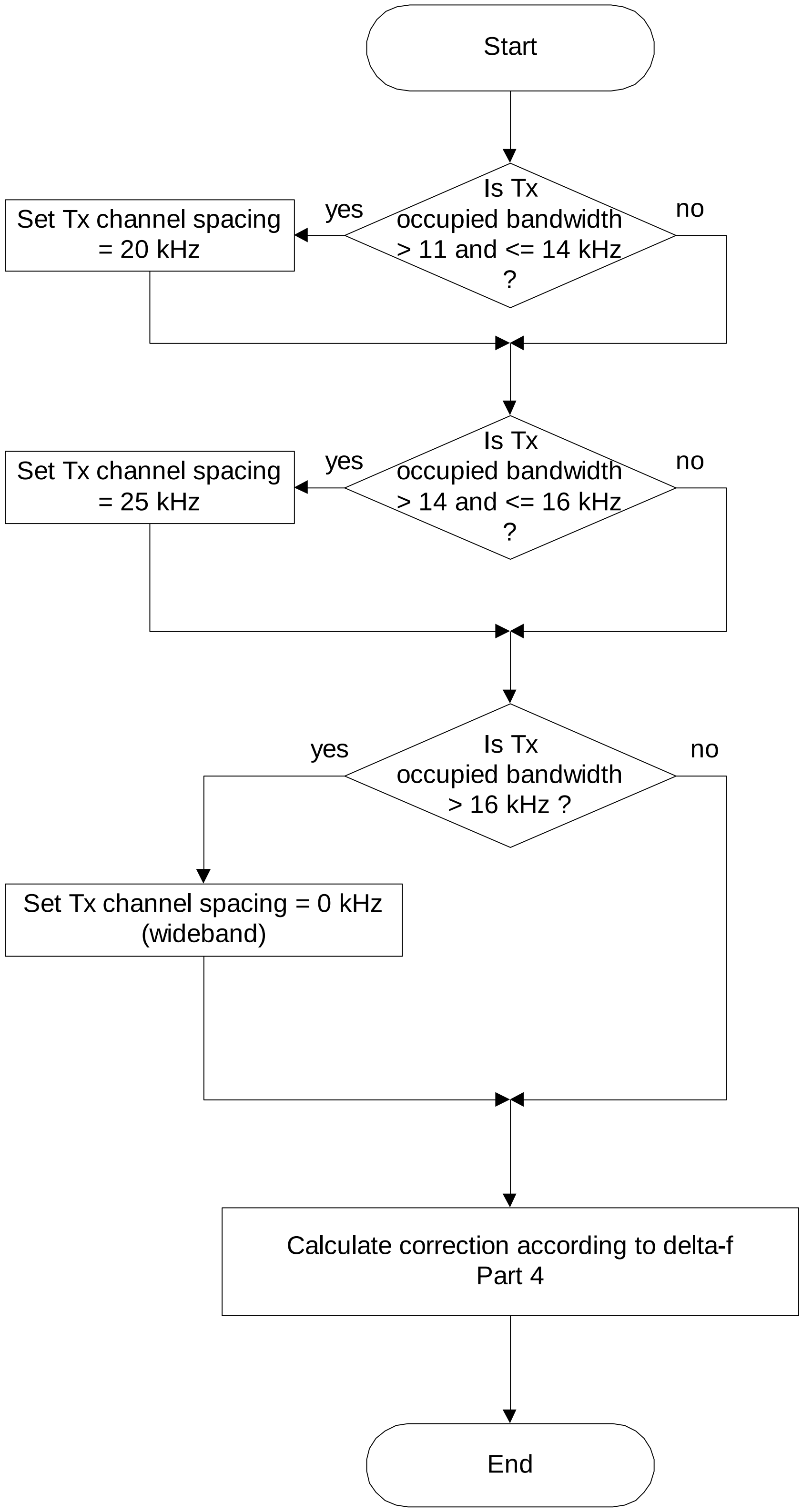
In this flow chart the Tx channel spacing is set according to the Tx occupied bandwidth.

If the Tx occupied bandwidth is less than or equal to 4.4 kHz, then the Tx channel spacing is set to 5 kHz.
If the Tx occupied bandwidth is between 4.4 and 5.5 kHz, then the Tx channel spacing is set to 6.25 kHz.
If the Tx occupied bandwidth is between 5.5 and 8.8 kHz, then the Tx channel spacing is set to 10 kHz.
If the Tx occupied bandwidth is between 8.8 and 11 kHz, then the Tx channel spacing is set to 12.5 kHz.

Calculate correction according to delta-f for normal HCM Agreement Part 3

This process is described in the next flow chart.

Chapter 4.1: Calculate correction according to delta-f Part 3



Calculate correction according to delta-f for normal HCM Agreement

Part 3

In this flow chart the Tx channel spacing is set according to the Tx occupied bandwidth.

If the Tx occupied bandwidth is between 11 and 14 kHz, then the Tx channel spacing is set to 20 kHz.
If the Tx occupied bandwidth is between 14 and 16 kHz, then the Tx channel spacing is set to 25 kHz.

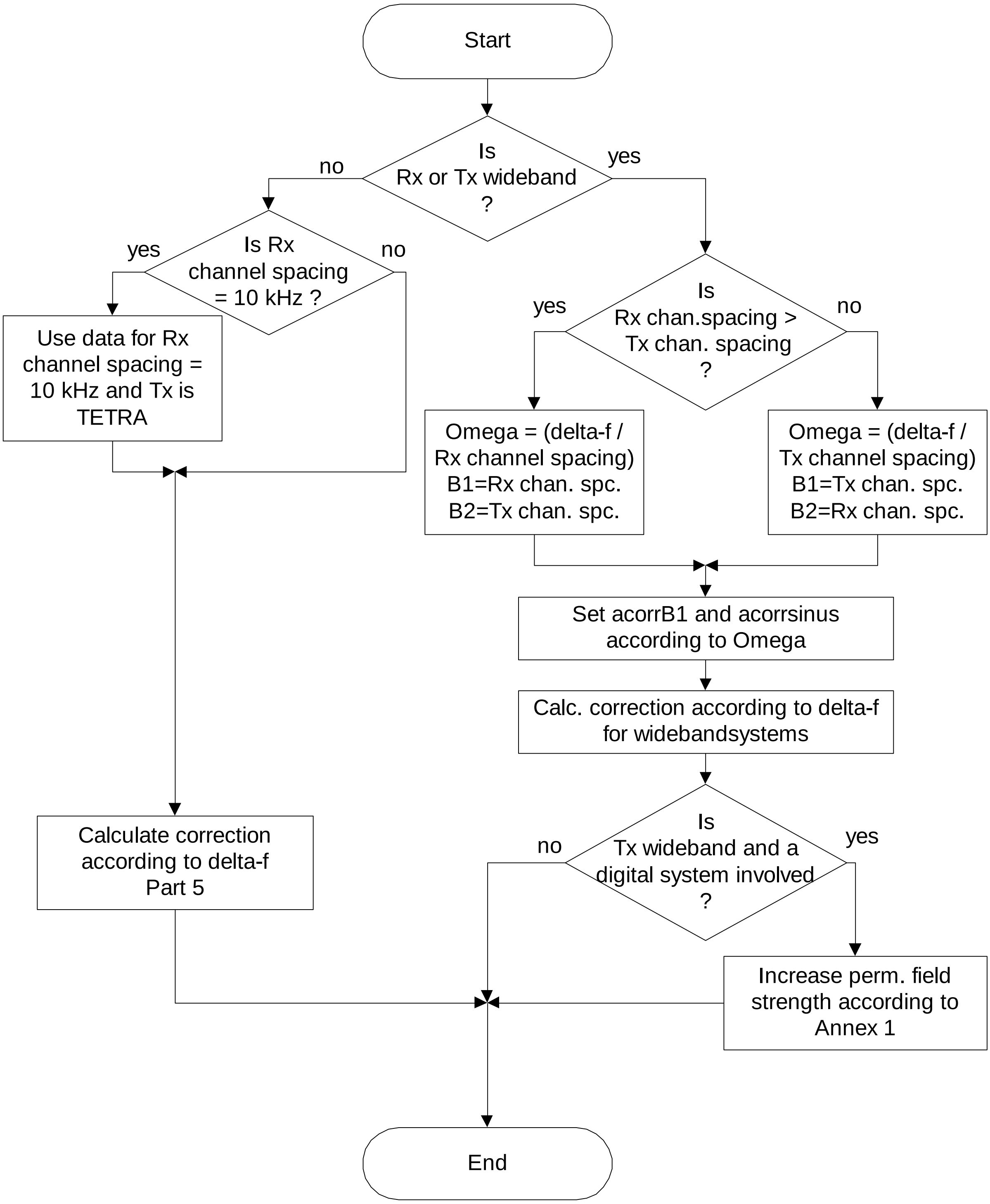
Is Tx occupied bandwidth > 16 kHz?

If the Tx occupied bandwidth is greater than 16 kHz, then the Tx channel spacing is set to 0 to indicate that the transmitter is belonging to a wideband system.

Calculate correction according to delta-f for normal HCM Agreement Part 4

This process is described in the next flow chart.

Chapter 4.1: Calculate correction according to delta-f
Part 4



Calculate correction according to delta-f for normal HCM Agreement

Part 4

This Part 4 of the subroutine determines the set of used data for calculating the correction factor for Rx channel spacing equal to 10 kHz and for wideband systems.

This flow chart shows the first part of the data selection for the calculation of the correction according to delta-f.

Use data for Rx channel spacing = 10 kHz and Tx is TETRA

The use data for Rx channel means that the relevant set of data is prepared for later calculation. (They are stored in special buffer). This explanation is also valid for the following flow charts of this procedure.

Is Rx chan. spacing > Tx chan. spacing?

Depending on the biggest channel spacing, the values for O, B1 and B2 are set.

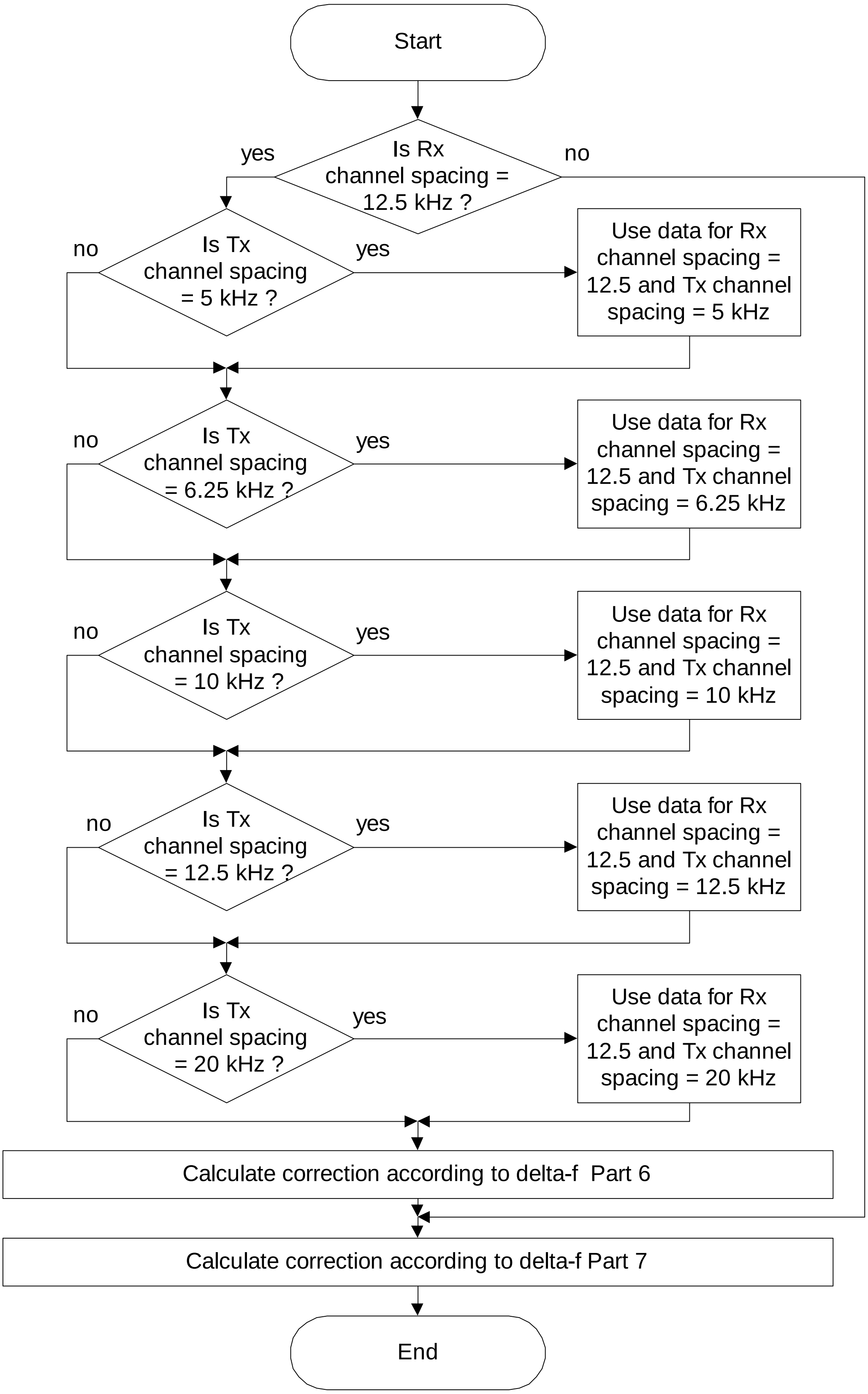
Increase perm. fieldstrenght according to Annex 1

If the interferer is a wideband system and a digital system is involved, the formula of Annex 1 is applied to correct the permissible interference fieldstrenght.

Calculate correction according to delta-f for normal HCM Agreement Part 5

This process is described in the next flow chart.

Chapter 4.1: Calculate correction according to delta-f
Part 5



Calculate correction according to delta-f for normal HCM Agreement

Part 5

This flow chart shows the second part of the data selection for the calculation of the correction according to delta-f.

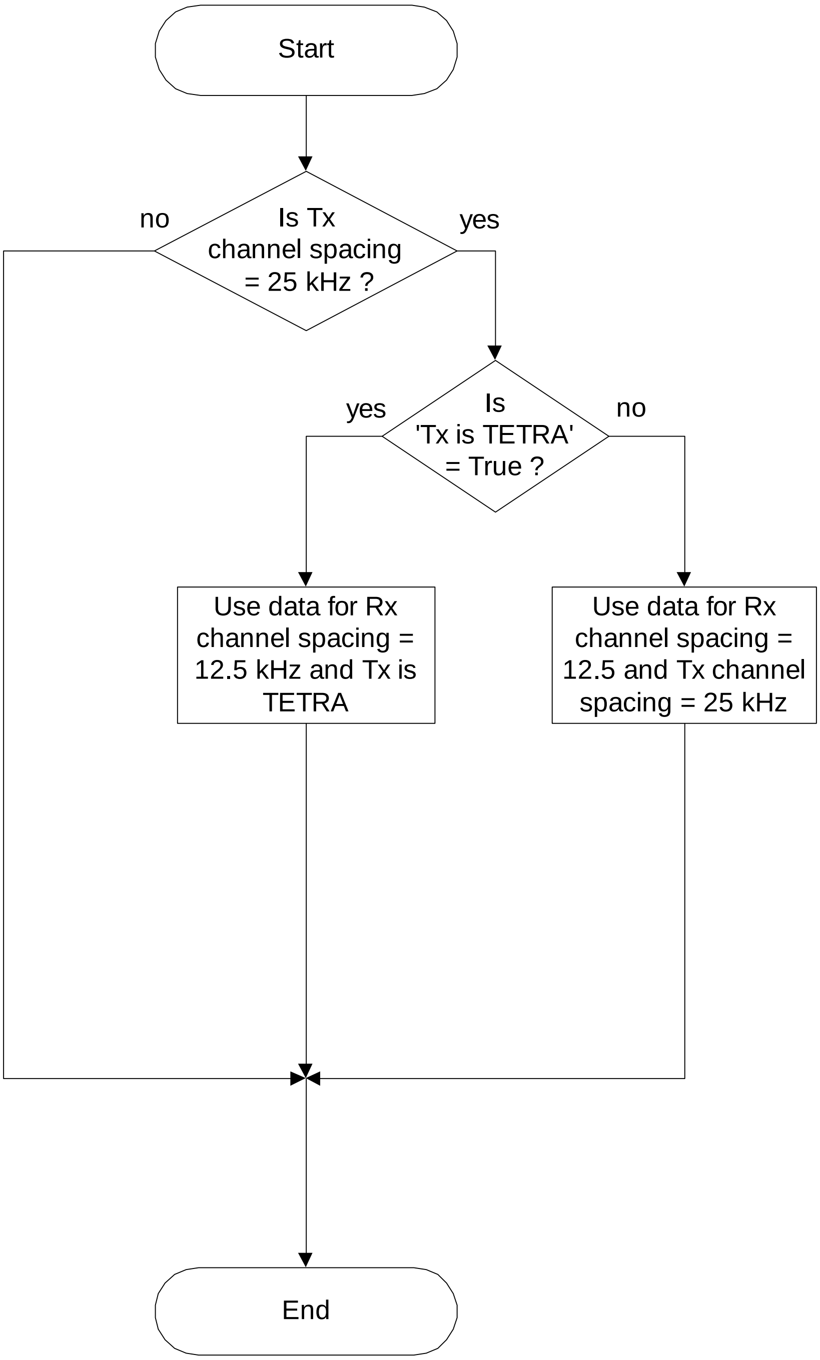
Calculate correction according to delta-f for normal HCM Agreement Part 6

This process is described in the next flow chart.

Calculate correction according to delta-f for normal HCM Agreement Part 7

This process is described in the next but one flow chart.

Chapter 4.1: Calculate correction according to delta-f
Part 6

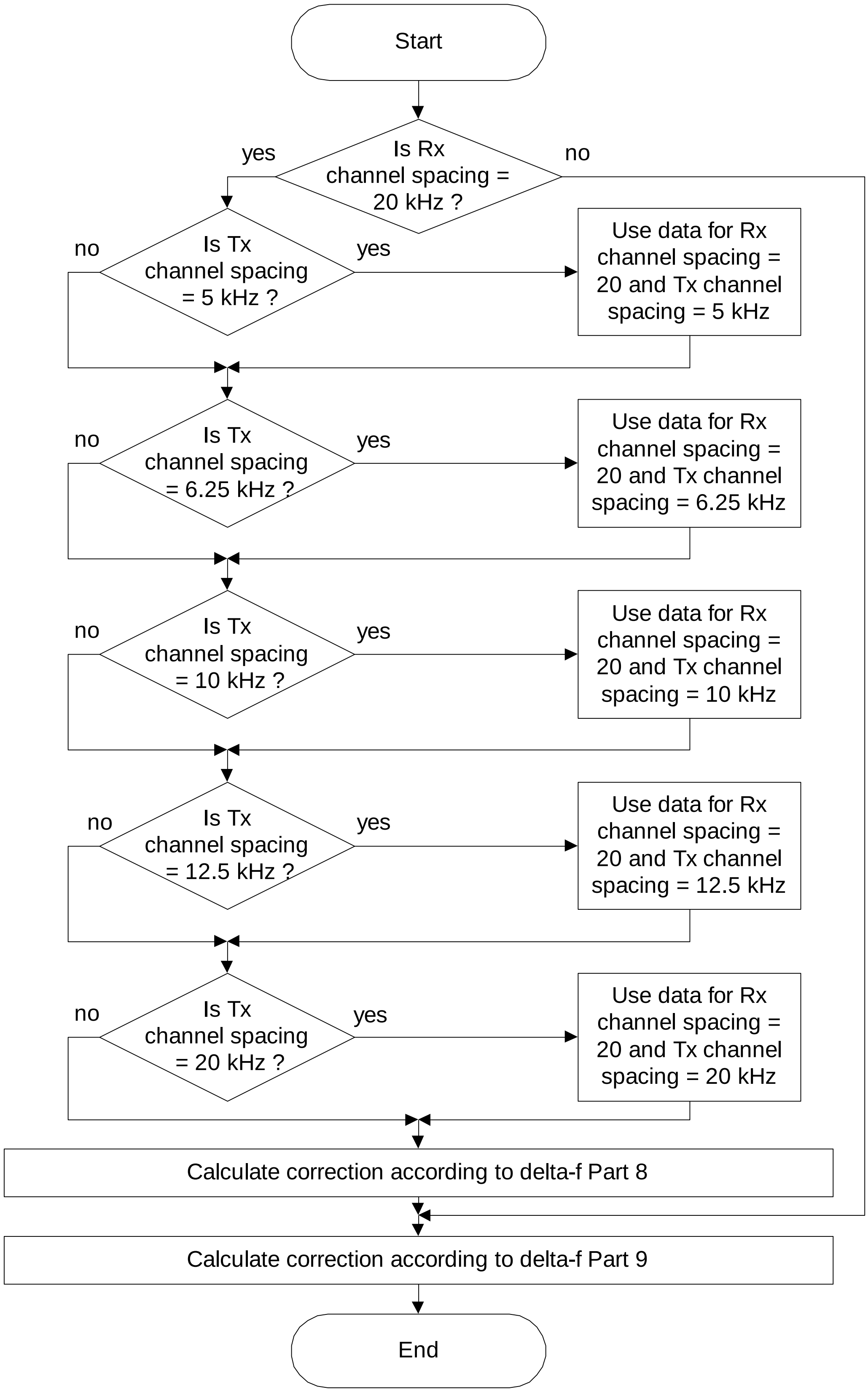


Calculate correction according to delta-f for normal HCM Agreement

Part 6

This flow chart shows the third part of the data selection for the calculation of the correction according to delta-f.
If Tx = TETRA, the curves of Annex 3A for the increase of the permissible interference fieldstrenght for analogue receivers interfered by a TETRA signal are applied.

Chapter 4.1: Calculate correction according to delta-f
Part 7



Calculate correction according to delta-f for normal HCM Agreement

Part 7

This flow chart shows the fourth part of the data selection for the calculation of the correction according to delta-f.

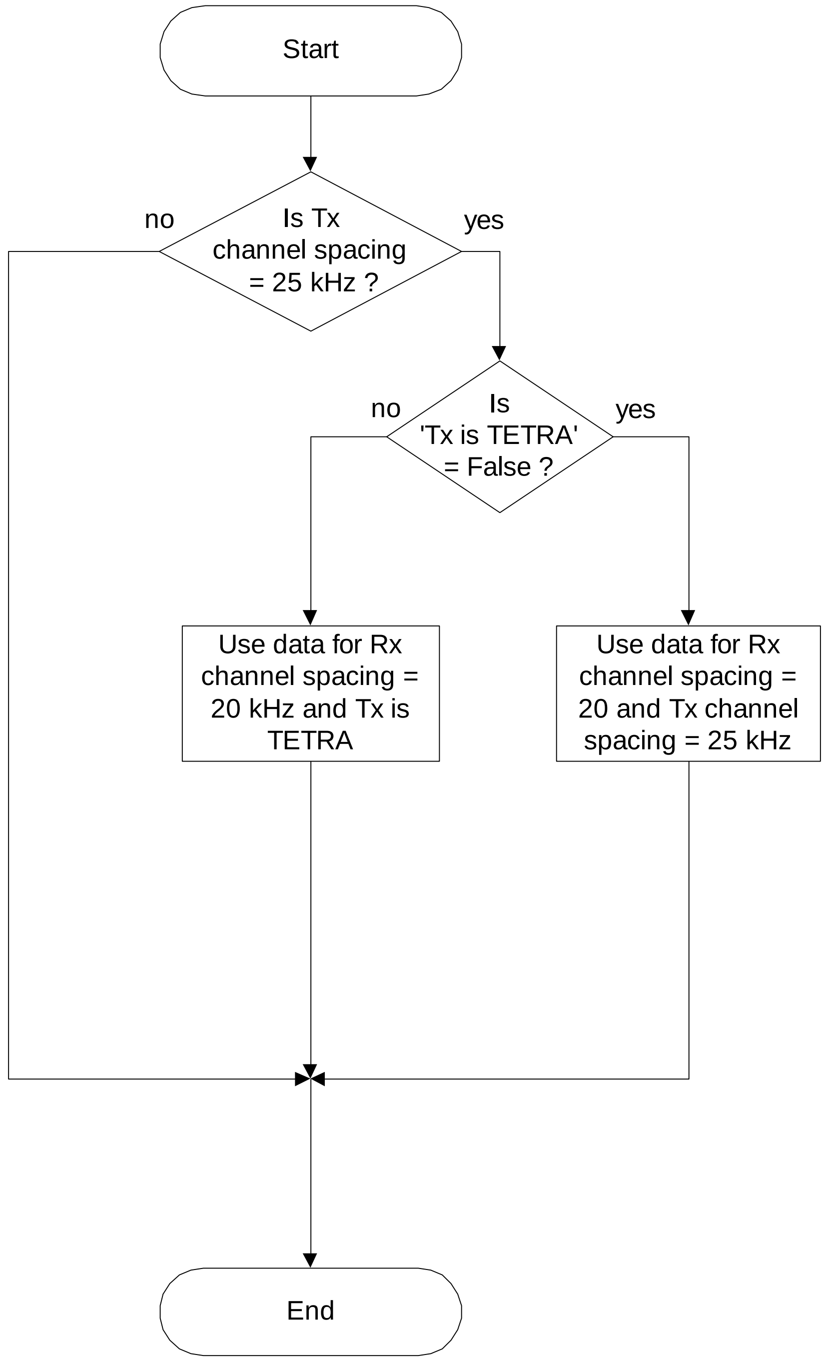
Calculate correction according to delta-f for normal HCM Agreement Part 8

This process is described in the next flow chart.

Calculate correction according to delta-f for normal HCM Agreement Part 9

This process is described in the next but one flow chart.

Chapter 4.1: Calculate correction according to delta-f
Part 8

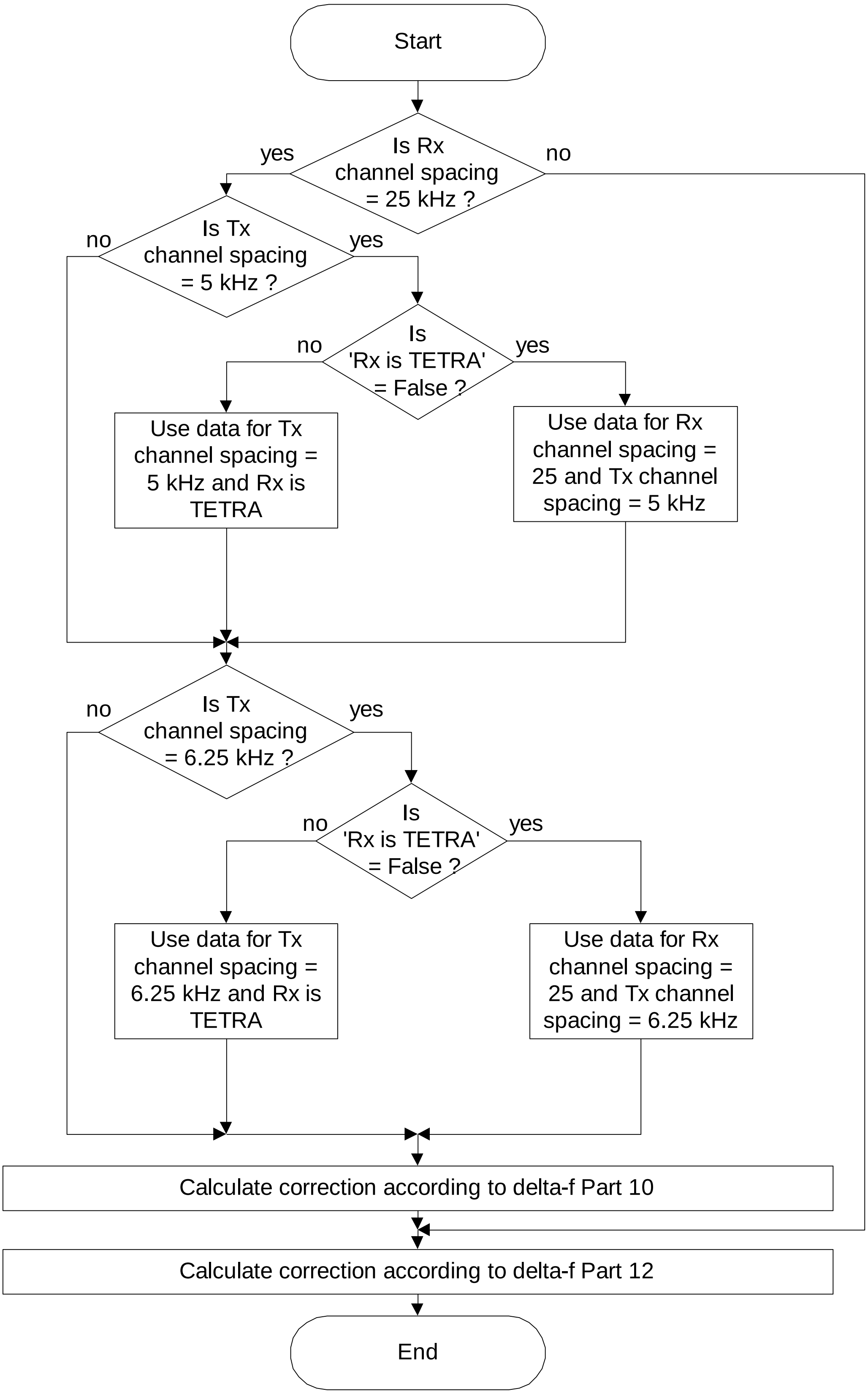


Calculate correction according to delta-f for normal HCM Agreement

Part 8

This flow chart shows the fifth part of the data selection for the calculation of the correction according to delta-f.
If Tx = TETRA, the curves of Annex 3A for the increase of the permissible interference fieldstrenght for analogue receivers interfered by a TETRA signal are applied.

Chapter 4.1: Calculate correction according to delta-f
Part 9



Calculate correction according to delta-f for normal HCM Agreement

Part 9

This flow chart shows the sixth part of the data selection for the calculation of the correction according to delta-f.
If Rx = TETRA, the curves of Annex 3A for the increase of the permissible interference fieldstrenght for TETRA receivers interfered by an analogue signal are applied.

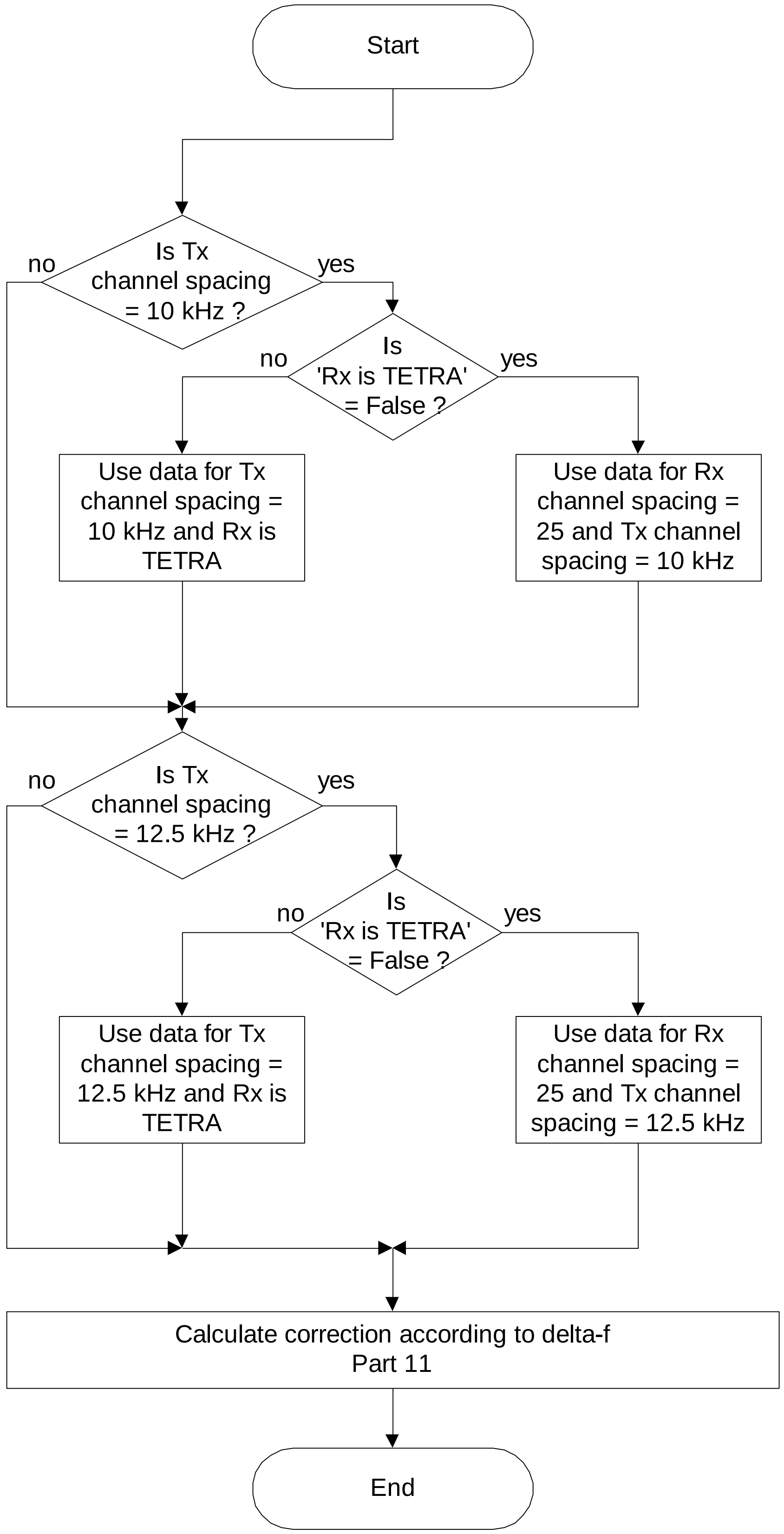
Calculate correction according to delta-f for normal HCM Agreement Part 10

This process is described in the next flow chart.

Calculate correction according to delta-f for normal HCM Agreement Part 12

This process is described in the next but two flow chart.

Chapter 4.1: Calculate correction according to delta-f
Part 10



Calculate correction according to delta-f for normal HCM Agreement

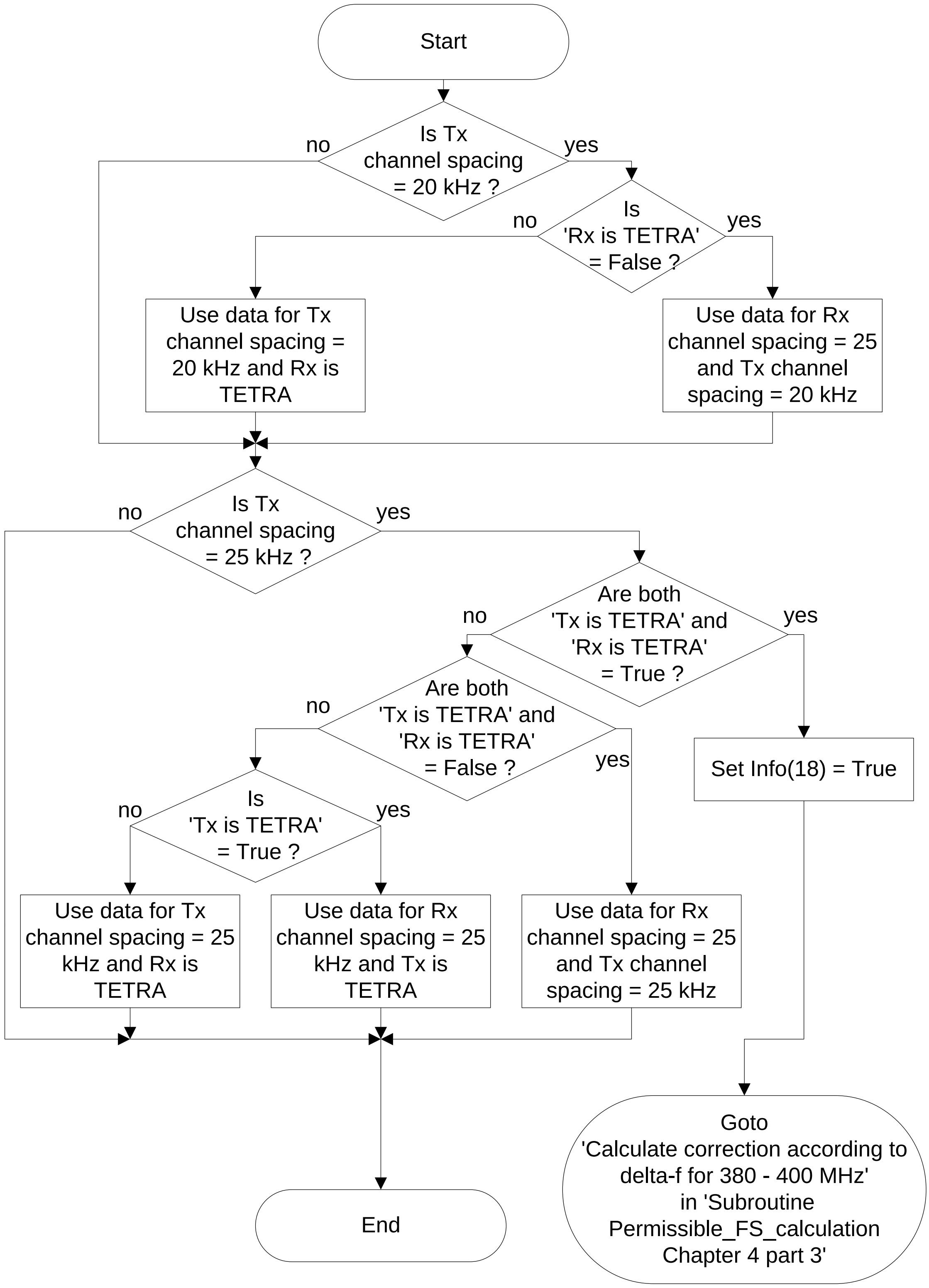
Part 10

This flow chart shows the seventh part of the data selection for the calculation of the correction according to delta-f.
If Rx = TETRA, the curves of Annex 3A for the increase of the permissible interference fieldstrenght for TETRA receivers interfered by an analogue signal are applied.

Calculate correction according to delta-f for normal HCM Agreement Part 11

This process is described in the next flow chart.

Chapter 4.1: Calculate correction according to delta-f
Part 11



Calculate correction according to delta-f for normal HCM Agreement

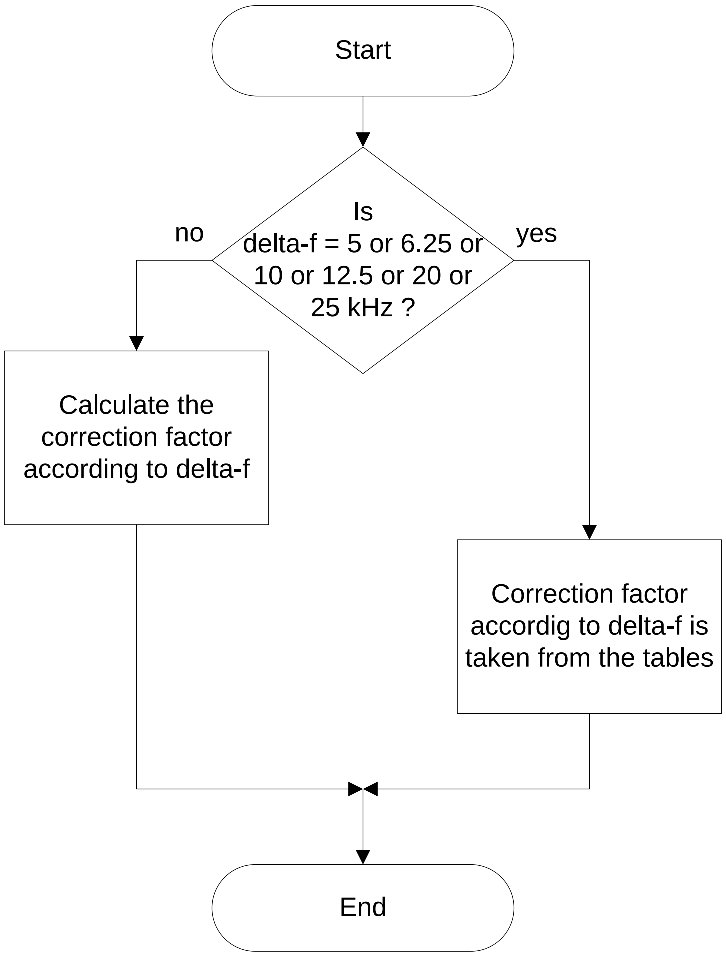
Part 11

This flow chart shows the eighth part of the data selection for the calculation of the correction according to delta-f.

Are both ‘Tx is TETRA’ and ‘Rx is TETRA’ = True ?

If Tx and Rx are TETRA systems the Info(18) value is set and the correction factor according to delta-f is calculated for the frequency band 380 – 400 MHz (see chapter 4.4)

Chapter 4.1: Calculate correction according to delta-f
Part 12

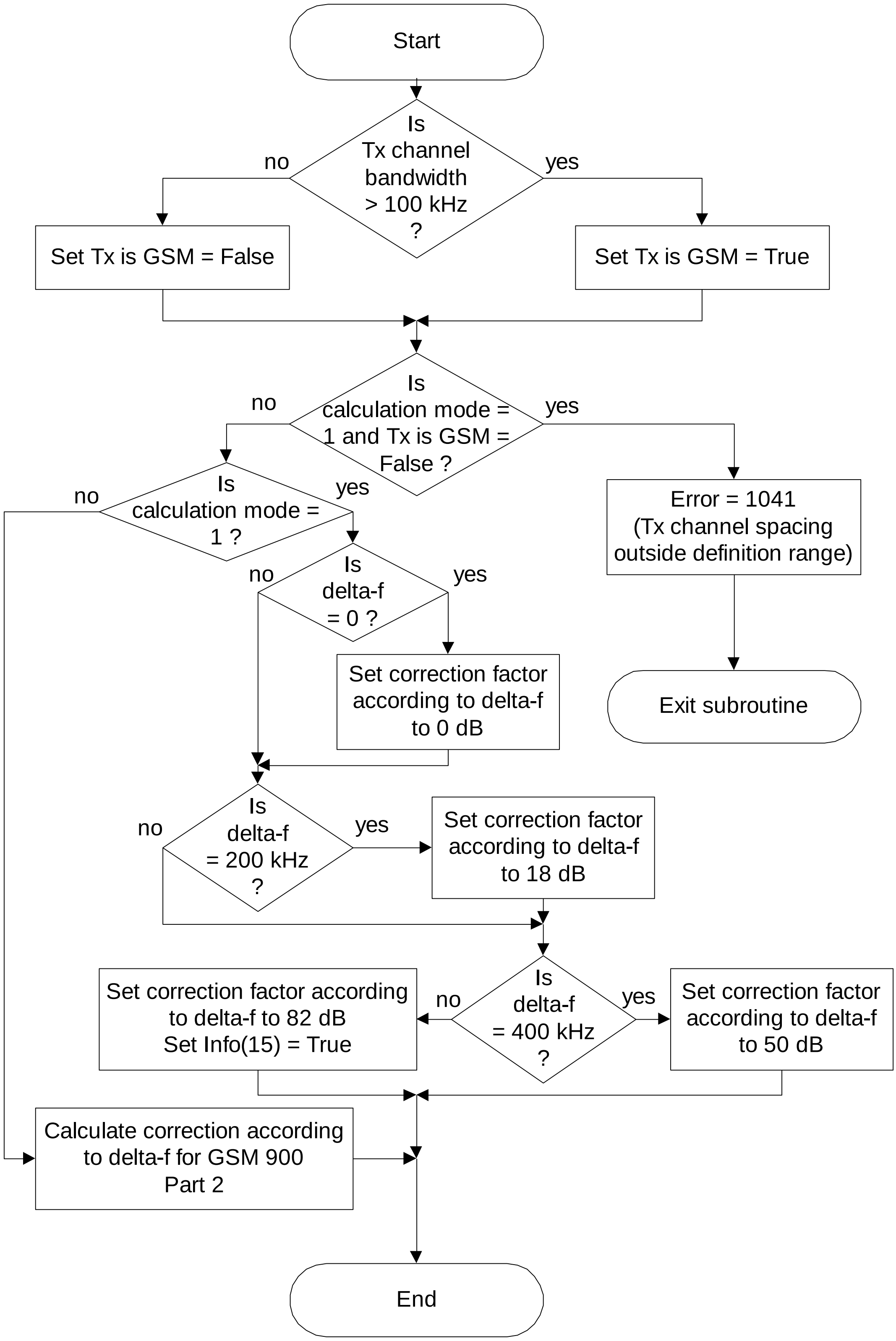


Calculate correction according to delta-f for normal HCM Agreement

Part 12

If the frequency difference delta-f is one of the nominal frequency differences 5, 6.25, 10, 12.5, 20 or 25 kHz, then the correction factor according to delta-f is set to the respective nominal correction factor, else it is calculated (interpolated).

Chapter 4.2: Calculate correction according to delta-f for GSM 900
Part 1



Chapter 4.2: Calculate correction according to delta-f for GSM900

Part 1

First, it is decided if Tx is GSM or not (if not, Rx is GSM).

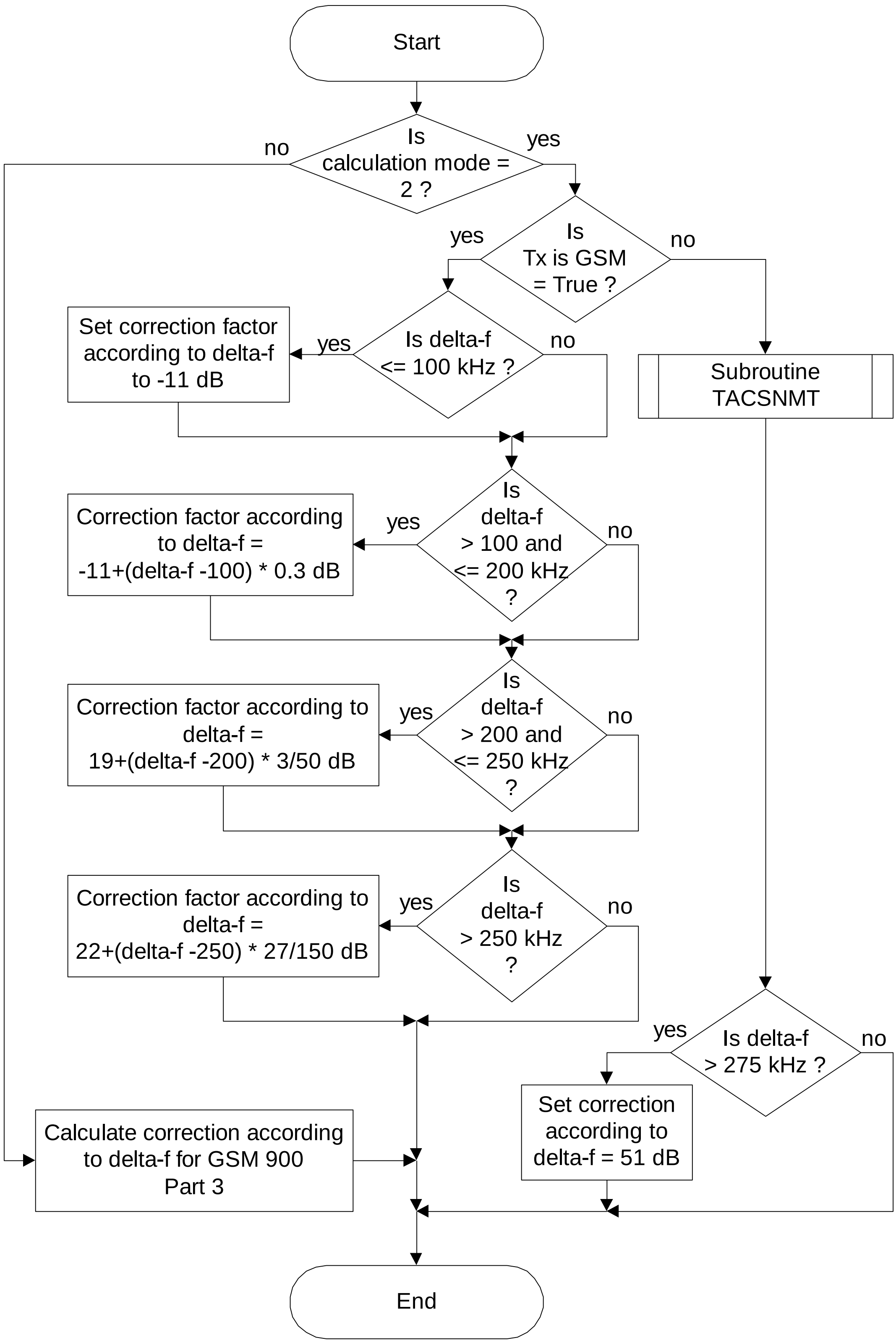
Is calculation mode = 1?

If the calculation mode is 1, then the correction according to delta-f is set according to the frequency difference:
If delta-f = 0, then the correction according to delta-f = 0,
if delta_f = 200 kHz, then the correction according to delta-f = 18 dB,
if delta_f = 400 kHz, then the correction according to delta-f = 50 dB,
and if delta_f > 400 kHz, then the correction according to delta-f = 82 dB.

Calculate correction according to delta-f for GSM900 Part2

This process is described in the next flow chart.

Chapter 4.2: Calculate correction according to delta-f for GSM 900 Part 2



Calculate correction according to delta-f for GSM900

Part 2

This process describes the situation when GSM interfers TACS.

Is calculation mode = 2?

If the calculation mode is 2 and Tx is a GSM, then the correction according to delta-f is set according to the frequency difference:

Subroutine TACSNMT

This subroutine describes the situation when TACS or NMT interfers GSM.
This process is described in chapter 4.2.1.

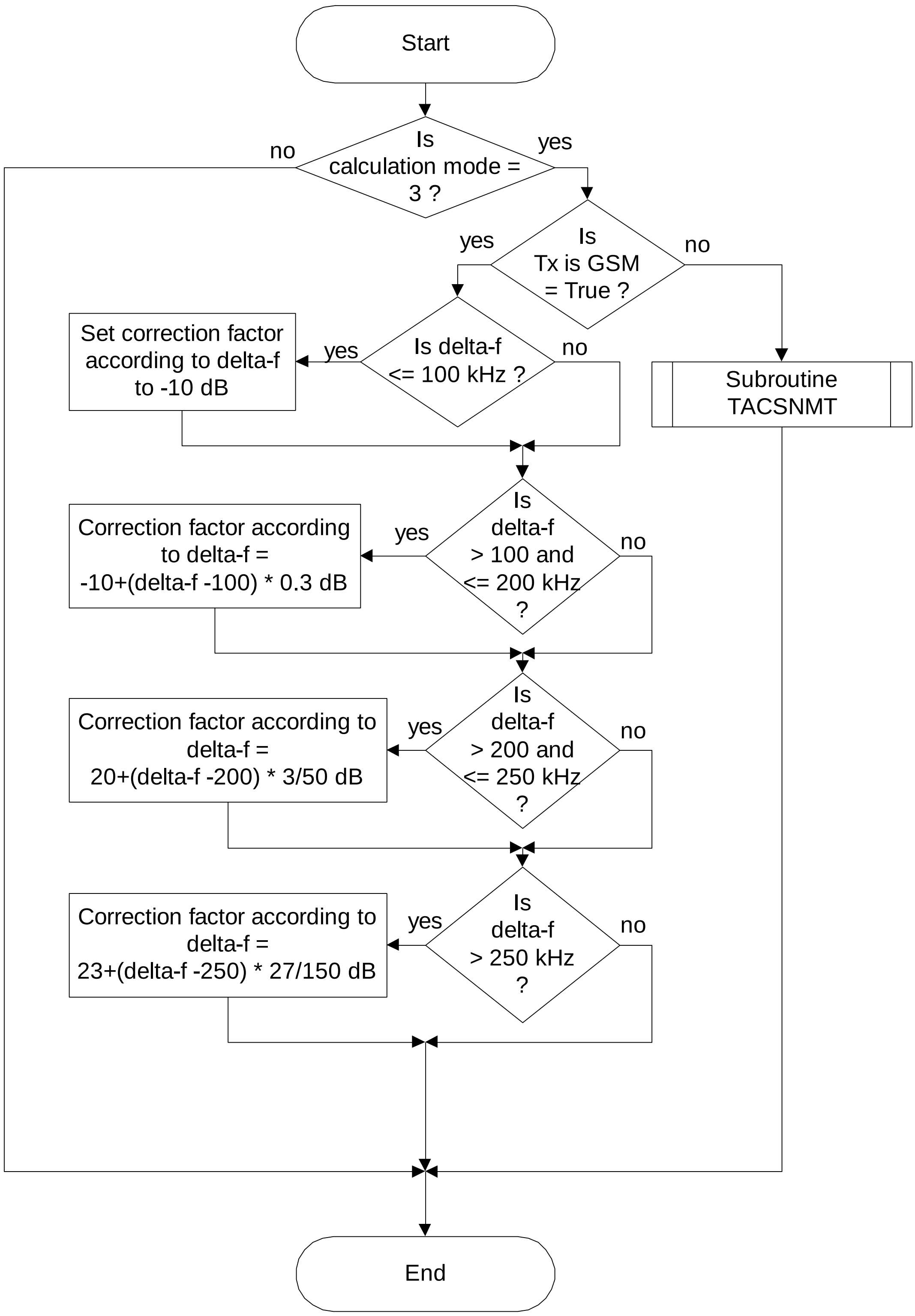
Set correction according to delta-f = 51 dB

Because the subroutine TACSNMT is used for TACS and for NMT, this subroutine includes the maximum correction factor of 61 dB for NMT. For TACS, this maximum correction factor is 51 dB.

Calculate correction according to delta-f for GSM900 Part3

This process is described in the next flow chart.

Chapter 4.2: Calculate correction according to delta-f for GSM 900
Part 3



Calculate correction according to delta-f for GSM900

Part 3

This process describes the situation when GSM interfers NMT.

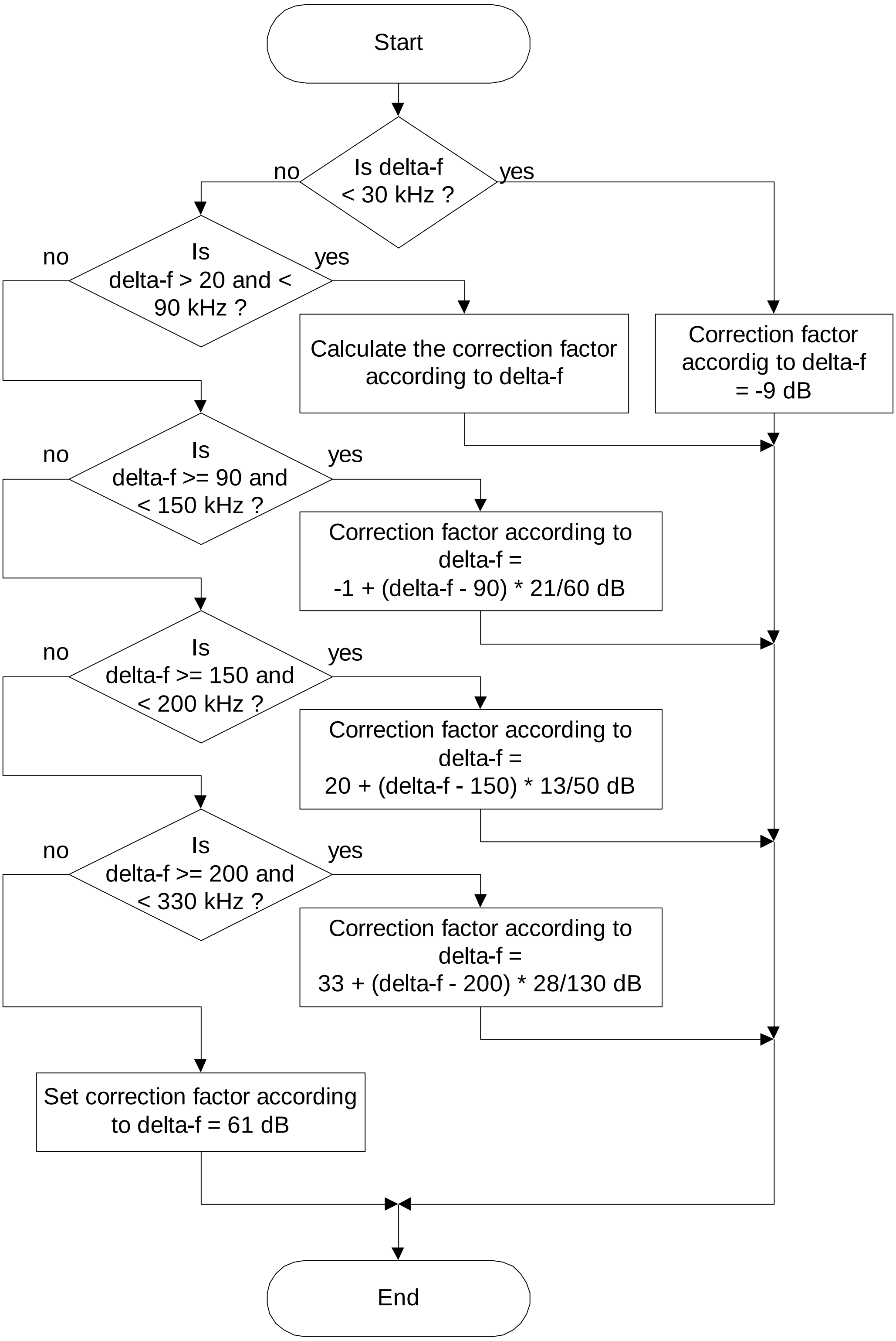
Is calculation mode = 3?

If the calculation mode is 3 and Tx is a GSM, then the correction according to delta-f is set according to the frequency difference.

Subroutine TACSNMT

This subroutine describes the situation when TACS or NMT interfers GSM.
This process is described in chapter 4.2.1.

Chapter 4.2.1: Subroutine TACSNMT

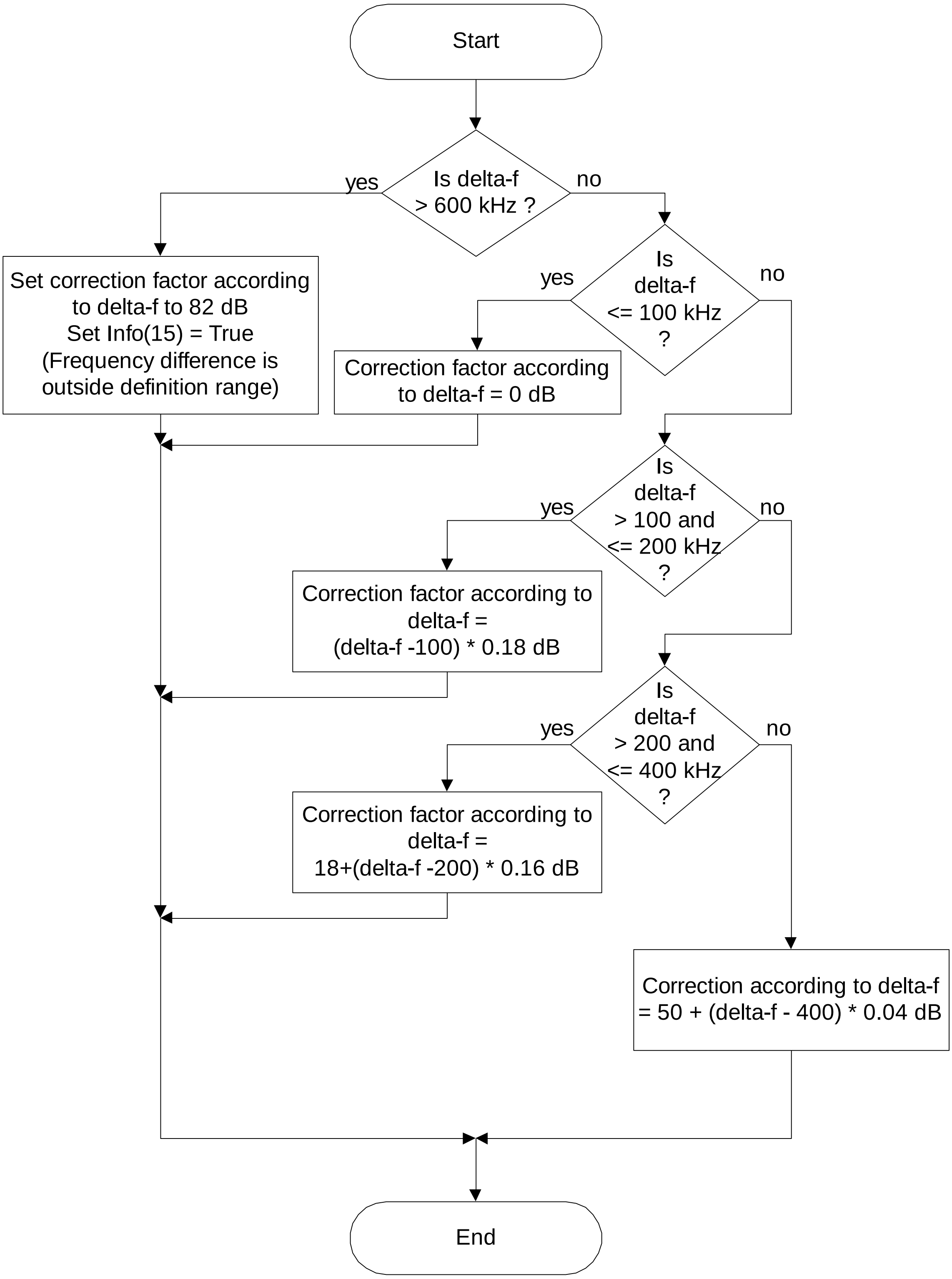


Chapter 4.2.1: Subroutine TACSNMT

Calculate the correction factor according to delta-f

The correction factor is interpolated according to the frequency difference.

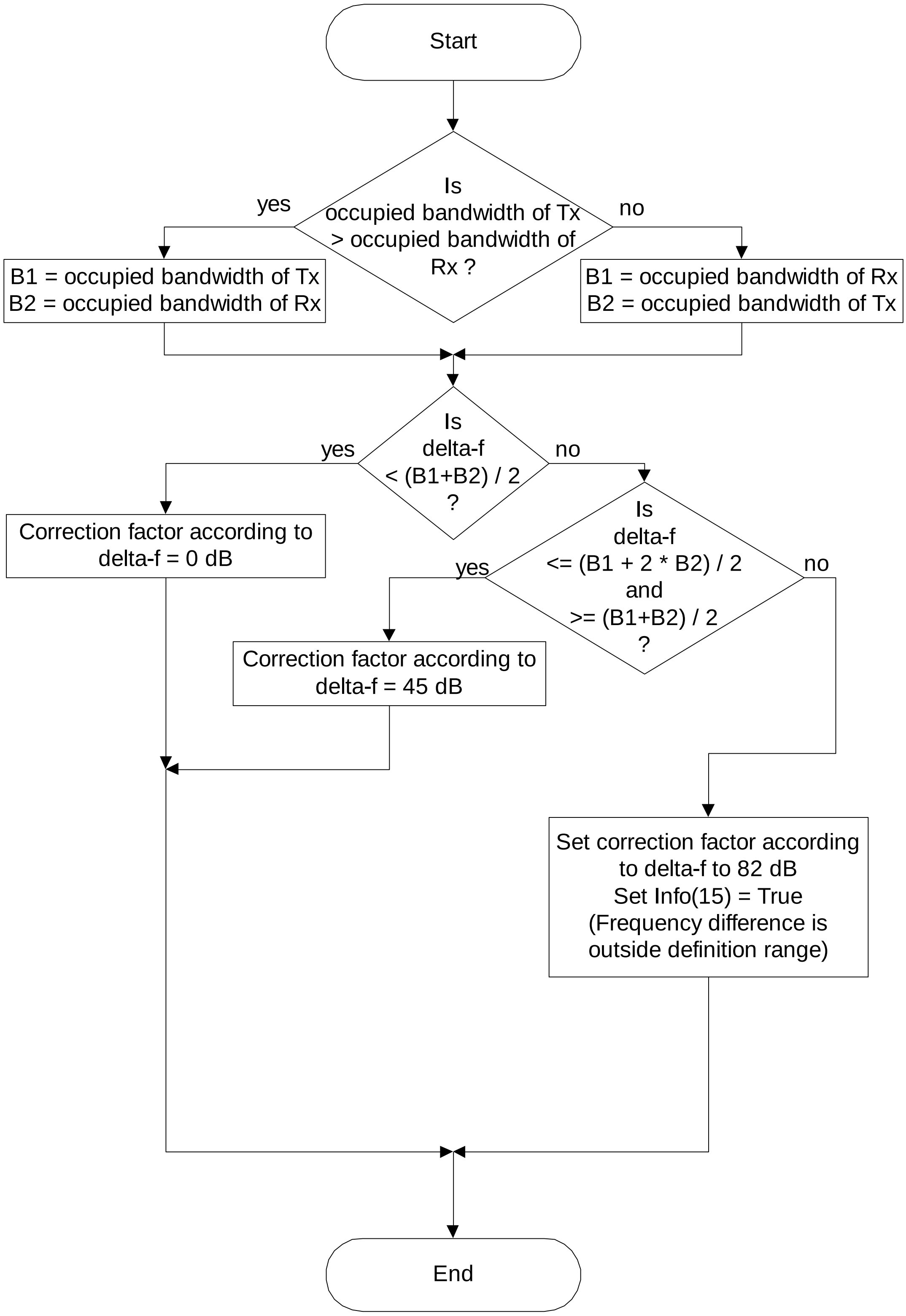
Chapter 4.3: Calculate correction according to delta-f for GSM 1800



Chapter 4.3: Calculate correction according to delta-f for GSM1800

The correction according to delta-f is set according to the frequency difference.

Chapter 4.4: Calculate correction according to delta-f for 380 - 400 MHz



Chapter 4.4: Calculate correction according to delta-f for 380 – 400 MHz

Is occupied bandwidth of Tx > occupied bandwidth of Rx?

If the occupied bandwidth of Tx is greater than the occupied bandwidth of Rx, then B1 is set to the occupied bandwidth of Tx and B2 is set to the occupied bandwidth of Rx, else B1 is set to the occupied bandwidth of Rx and B2 is set to the occupied bandwidth of Tx.

Is delta-f < (B1 + B2) / 2?

If delta-f is less than (B1 + B2) / 2, then the correction according to delta-f is set to 0, else it is calculated according to the frequency difference.

This page is intentionally left blank

Chapter 5: Common subroutines

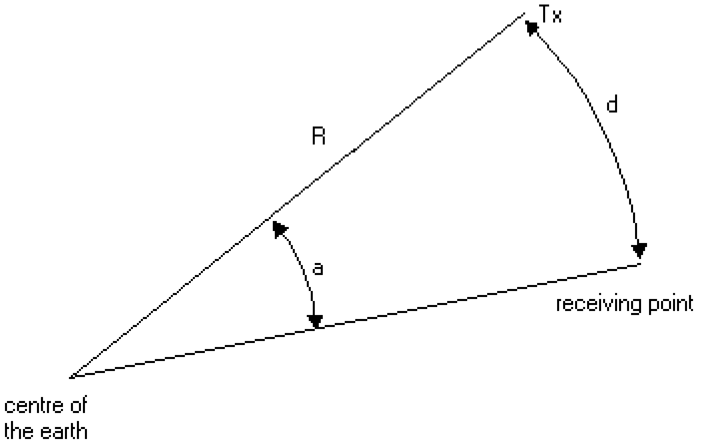
Chapter 5.1 Subroutine Calc_distance

Is longitude of point A = longitude of point B and latitude of point A = latitude of point B?

When the co-ordinates of Tx and the receiving point are equal the distance is set to 0 km.

Calculate distance:

Point 1 (Tx)	longitude = A	d = distance
	latitude = B	a = arc-distance
Point 2 (receiving point)	longitude = C	
	latitude = D	



Radius of the earth at the equator:	6378.137 km
Radius at the poles:	6356.752 km
Weighted radius of the earth R:	6371.0 km

Arc-distance on the great circle:

a = arcos (sin B * sin D + cos B * cos D * cos (C-A))

Weighted length of one degree of a great circle on the earth surface:

$$\frac{2R\pi}{360°} = 111.2 \text{ km}$$

Distance on the surface:

d[km] = 111.2 * a

This page is intentionally left blank

Chapter 5.2 Subroutine Calc_direction

This subroutine calculates the azimuth from point A to point B.

Calculate the azimuth:

The azimuth is calculated according to the formula

$$azimuth = \arccos \frac{\sin(LAB) - \sin(LAA) * \cos(D)}{\cos(LAA) * \sin(D)}$$

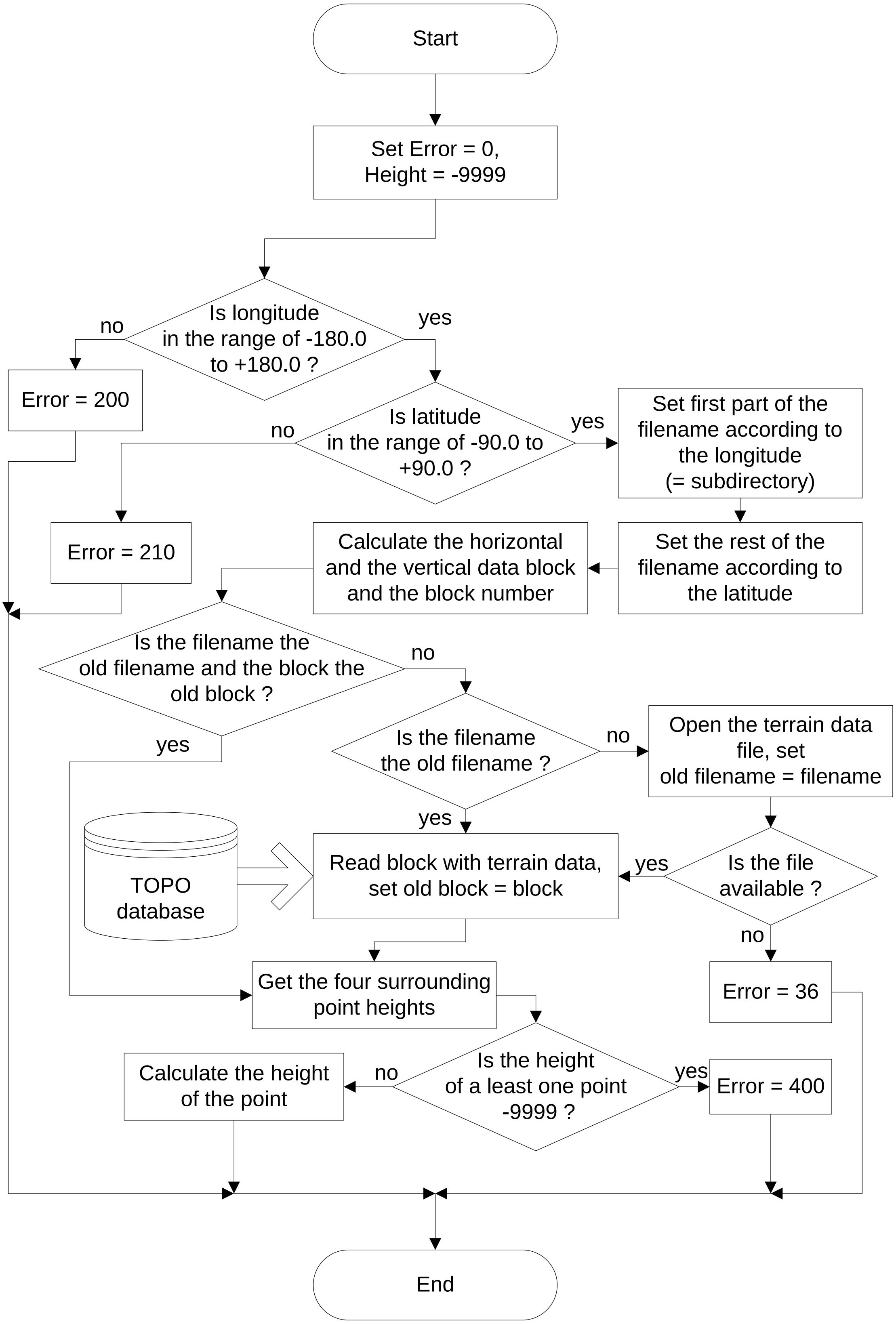
where

$$D = \arccos(\sin(LAA) * \sin(LAB) + \cos(LAA) * \cos(LAB) * \cos(LOB - LOA))$$

and where

LOA = longitude of point A
LAA = latitude of point A
LOB = longitude of point B
LAB = latitude of point B

Chapter 5.3: Subroutine Point_height



Chapter 5.3 Subroutine Point_height

This process determines the height of a point. The height information is stored in files on a disk. The structure of this files containing the height information is described in detail in Chapter 6.

Set first part of the filename according to the longitude (= subdirectory)

The first part of the filename is set using the longitude of the point (e.g. 'E015' for 15 degrees East).

Set the rest of the filename according to the latitude

The rest of the filename is set using the latitude of the point (e.g. 'N52' for 52 degrees North).
The ending of the filename is set using also the latitude. South of 50 degrees latitude, the resolution of the data in East – West direction is 3 seconds, north of 50 degrees latitude it is 6 seconds. Therefore the ending of the filename is set to '.33E' or '.63E'

Calculate the horizontal and the vertical data block and the block number

The data blocks and the block number are calculated using the co-ordinates of the point.

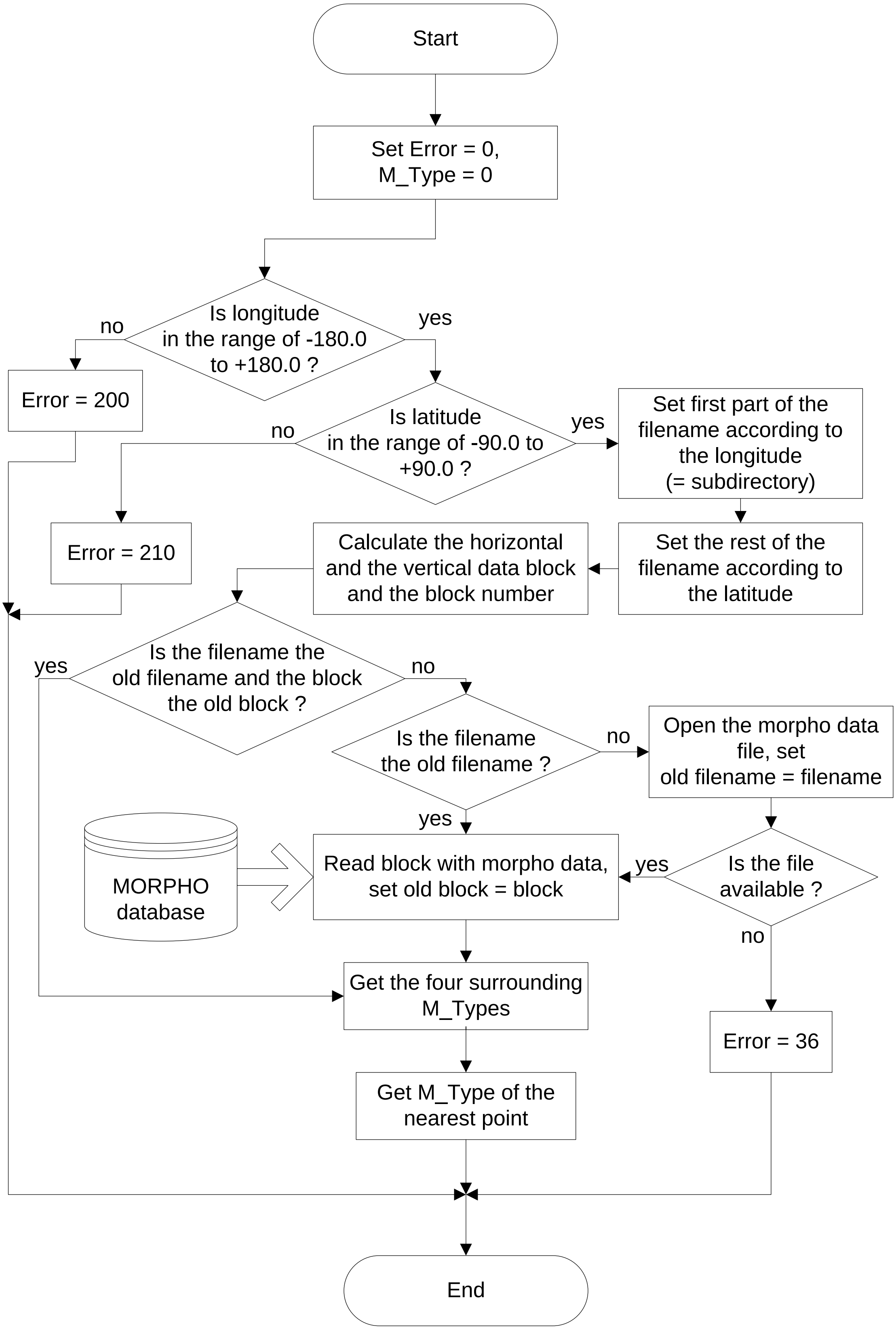
Get the four surrounding point heights

The heights of the 4 surrounding grid points are determined.

Calculate the height of the point

The resulting height is calculated by interpolating between the 4 surrounding points.

Chapter 5.4: Subroutine Point_type



Chapter 5.4 Subroutine Point_type

This process determines the morphological information of a point. The information is stored in files on a disk. The structure of this files containing the morphological information is described in detail in Chapter 7.

Set first part of the filename according to the longitude (= subdirectory)

The first part of the filename is set using the longitude of the point (e.g. 'E015' for 15 degrees East).

Set the rest of the filename according to the latitude

The rest of the filename is set using the latitude of the point (e.g. 'N52' for 52 degrees North).
The ending of the filename is set using also the latitude. South of 50 degrees latitude, the resolution of the data in East – West direction is 3 seconds, north of 50 degrees latitude it is 6 seconds. Therefore the ending of the filename is set to '.33M' or '.63M'

Calculate the horizontal and the vertical data block and the block number

The data blocks and the block number are calculated using the co-ordinates of the point.

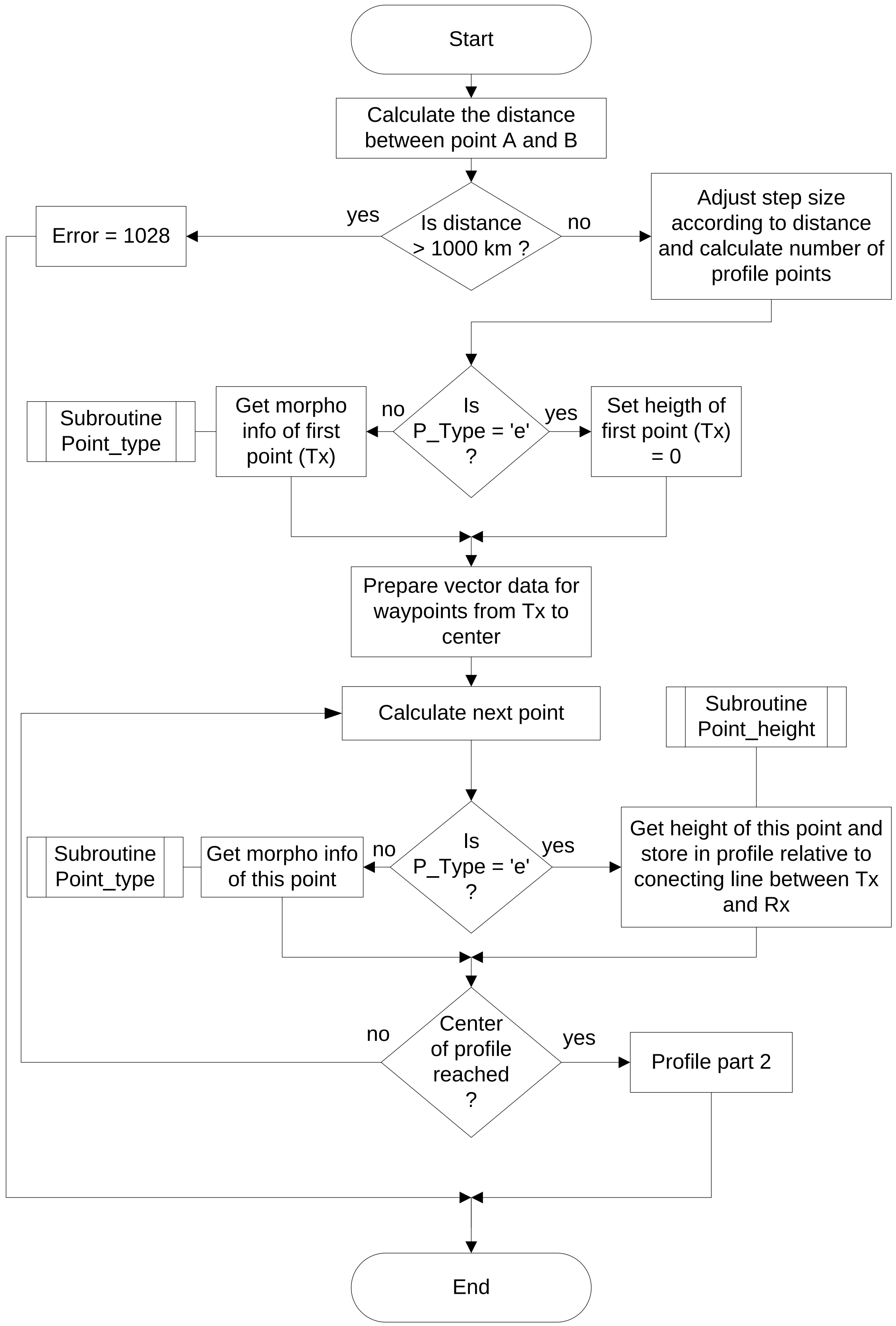
Get the four surrounding M-Types

The information of the 4 surrounding grid points is determined.

Get M-Type of the nearest point

The resulting morphological information is taken from the nearest point.

Chapter 5.5: Subroutine Profile part 1



Chapter 5.5 Subroutine Profile

This process determines the height profile or the morphological profile between two points.

Part 1

Calculate the distance between point A and B

The distance is calculated and if it is more than 1000 km, the HCM_error is set to 1028 and the subroutine terminates.

Adjust step size according to distance and calculate number of profile points

The input value (Point Distance) of step size (normally 100 m) is slightly modified to get an equal step size for all steps between transmitter and receiver position. This is done to ensure reciprocity.

Is P_Type = 'e'?

P_Type (Profile Type) is an input value for this subroutine which determines if the height profile (P_Type = e) or the morphological profile (P_Type = m) is calculated.
If the P_Type is 'e', then the height of point A is determined with the Point_height subroutine (see chapter 5.3); else the morphological information of point A is determined with the Point_type subroutine (see chapter 5.4).

Prepare vector data for waypoints from Tx to center

The vector equivalent to step size is transformed from direction and distance to spherical co-ordinates.

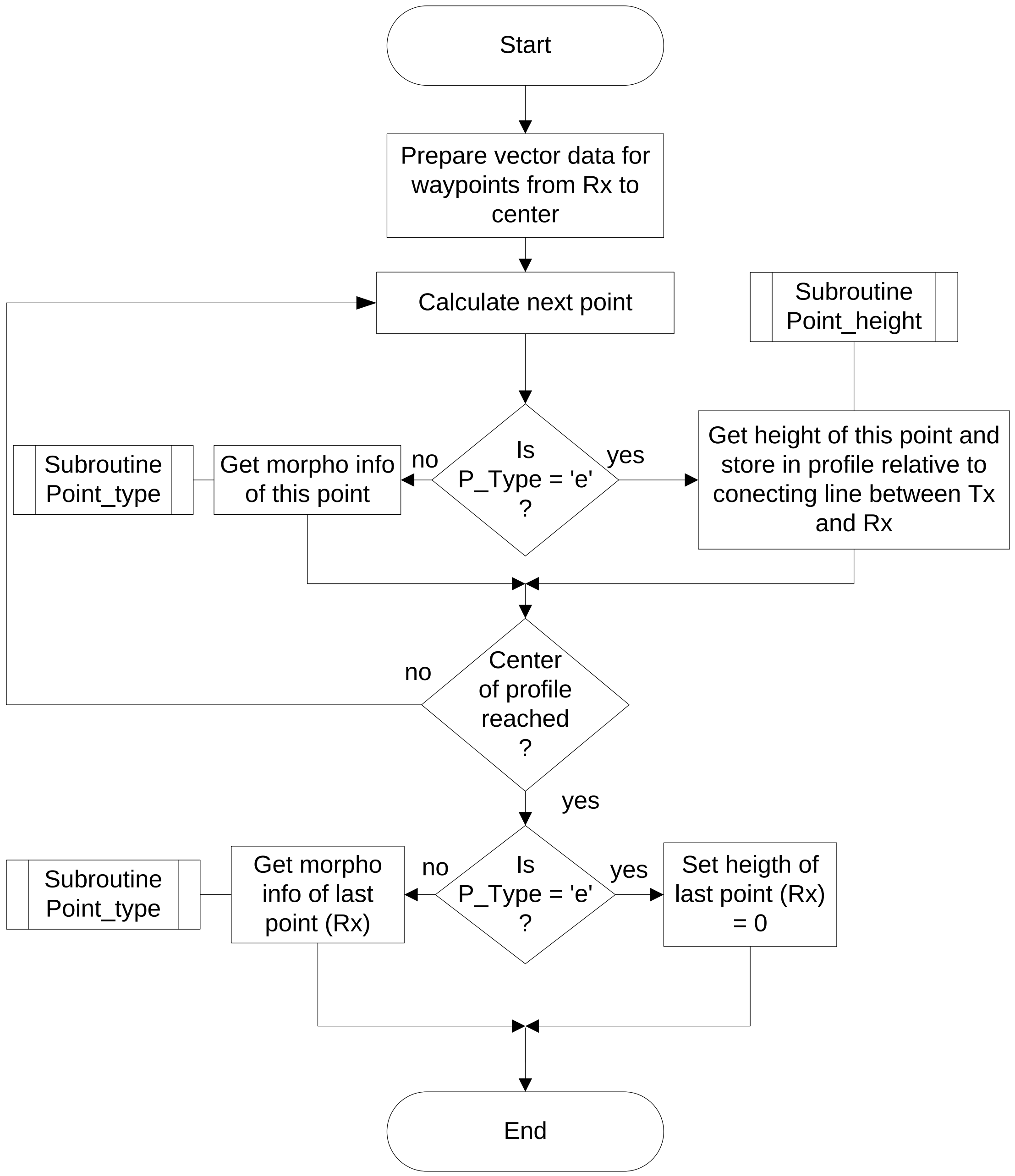
Calculate next point

The geographical co-ordinates of the next point are calculated.

Get height of this point and store in profile relative to connecting line between Tx and Rx

The terrain height of the point is read from the database and compared to the height of the point on the connecting line between the Tx and Rx location. The difference is stored in the profile. This assures reciprocity for calculations on propagation paths along sloping terrain.

Chapter 5.5: Subroutine Profile part 2



Subroutine Profile

Part 2

This process determines the height profile or the morphological profile between two points.

Prepare vector data for waypoints from Rx to center

The vector equivalent to step size is transformed from direction and distance to spherical co-ordinates.

Calculate next point

The geographical co-ordinates of the next point are calculated.

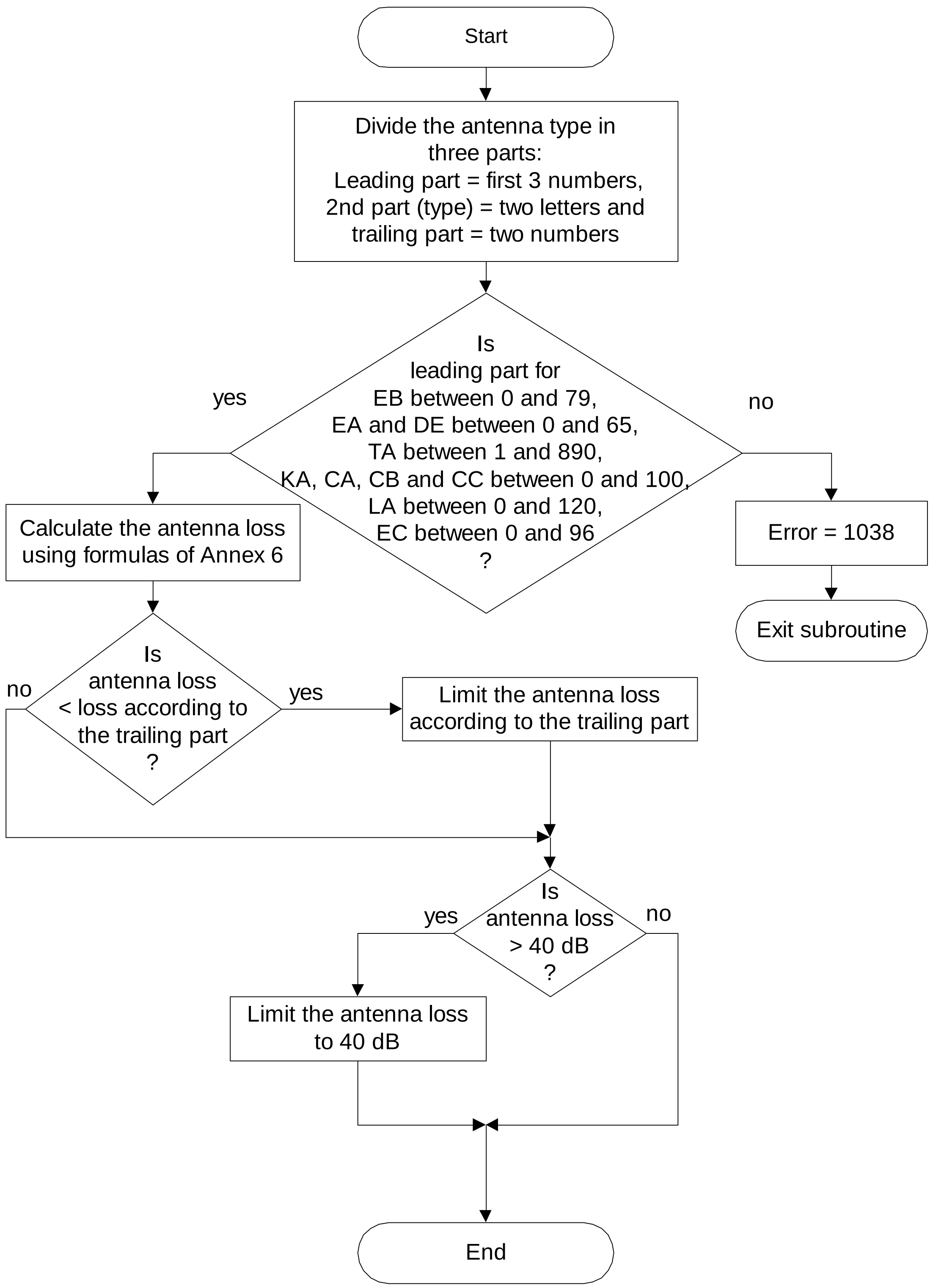
Is P_Type = 'e'?

P_Type (Profile Type) is an input value for this subroutine which determines if the height profile (P_Type = e) or the morphological profile (P_Type = m) is calculated.
If the P_Type is 'e', then the height of point A is determined with the Point_height subroutine (see chapter 5.3); else the morphological information of point A is determined with the Point_type subroutine (see chapter 5.4).

Get height of this point and store in profile relative to connecting line between Tx and Rx

The terrain height of the point is read from the database and compared to the height of the point on the connecting line between the Tx and Rx location. The difference is stored in the profile. This assures reciprocity for calculations on propagation paths along sloping terrain.

Chapter 5.6: Subroutine Antenna



Chapter 5.6 Subroutine Antenna

This process determines the loss of an antenna according to the radiation pattern in a given direction.

Divide the antenna type in three parts:

The first part of this subroutine splits the input antenna character string into three parts as described in point 1.1 of Annex 6 of the HCM Agreement:

- the leading part (first 3 numbers)
- the type (2 letters)
- the trailing part (last 2 numbers)

Is leading part for EB between 0 and 79, EA and DE between 0 and 65, TA between 1 and 890, KA, CA, CB and CC between 0 and 100, LA between 0 and 120, EC between 0 and 96?

This part of the subroutine checks if the leading part is in line with the antenna types limits as defined in Annex 6.

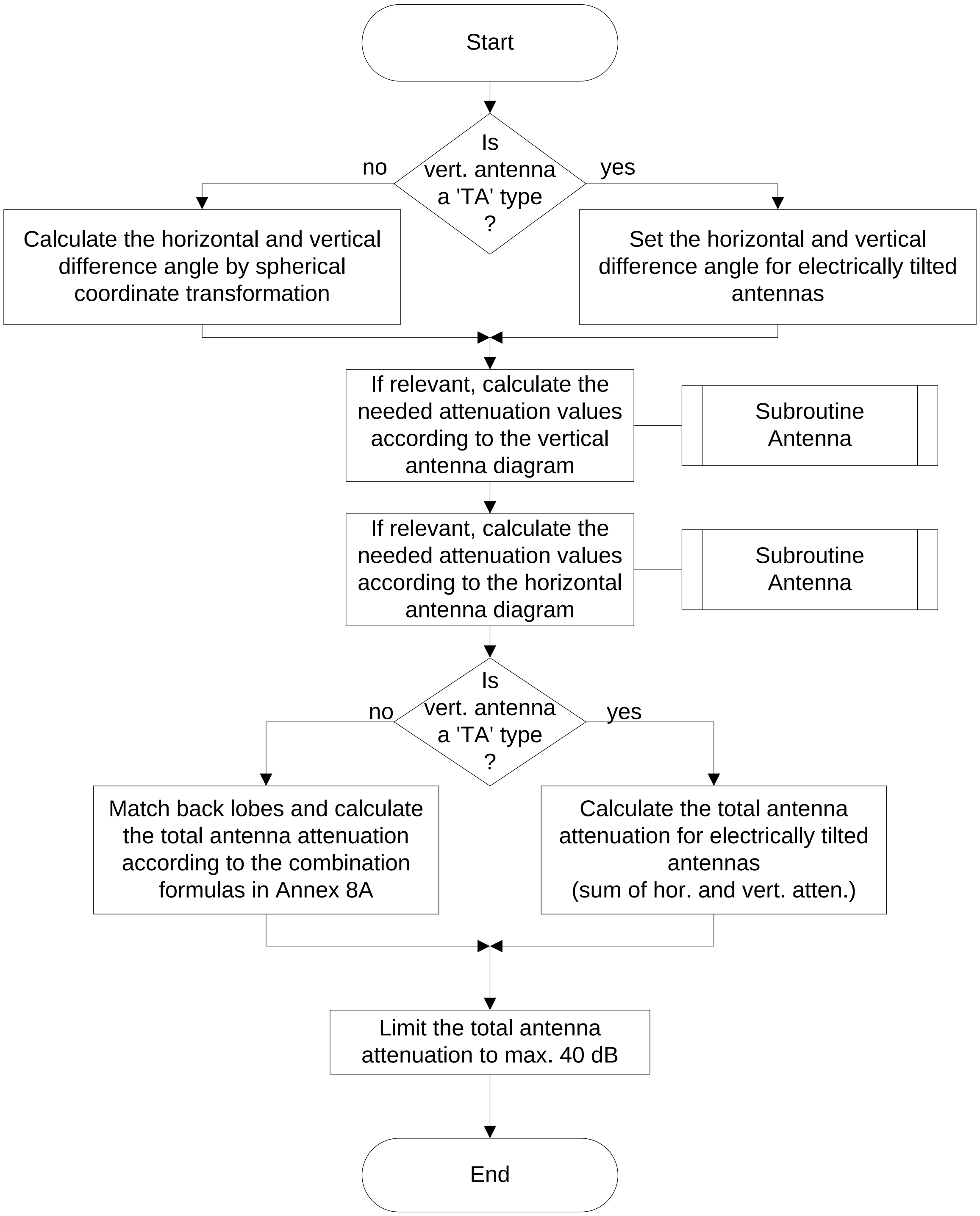
type	valid values for leading part
EA	001 - 065
EB	001 - 079
EC	001 - 096
DE	001 - 065
TA	001 - 890
LA	001 - 120
KA	000 - 100
CA	000 - 100
CB	000 - 100
CC	000 - 100

For other types no validation check is performed.

Calculate the antenna loss using formulas of Annex 6

For EA, EB, EC, DE, TA, LA, KA, CA, CB and CC type antennas, the angle and antenna code are used directly with the formulas in Annex 6 of the HCM Agreement to calculate the loss.
For V* and W* type antennas, the antenna code is further analyzed to derive the correct formula according to Appendix 4 & 5 to Annex 6 of the HCM Agreement.
For ND type antennas the loss is set to 0 dB.
The result is limited to -40 dB, giving an antenna loss in the range of -40 ... 0 dB.

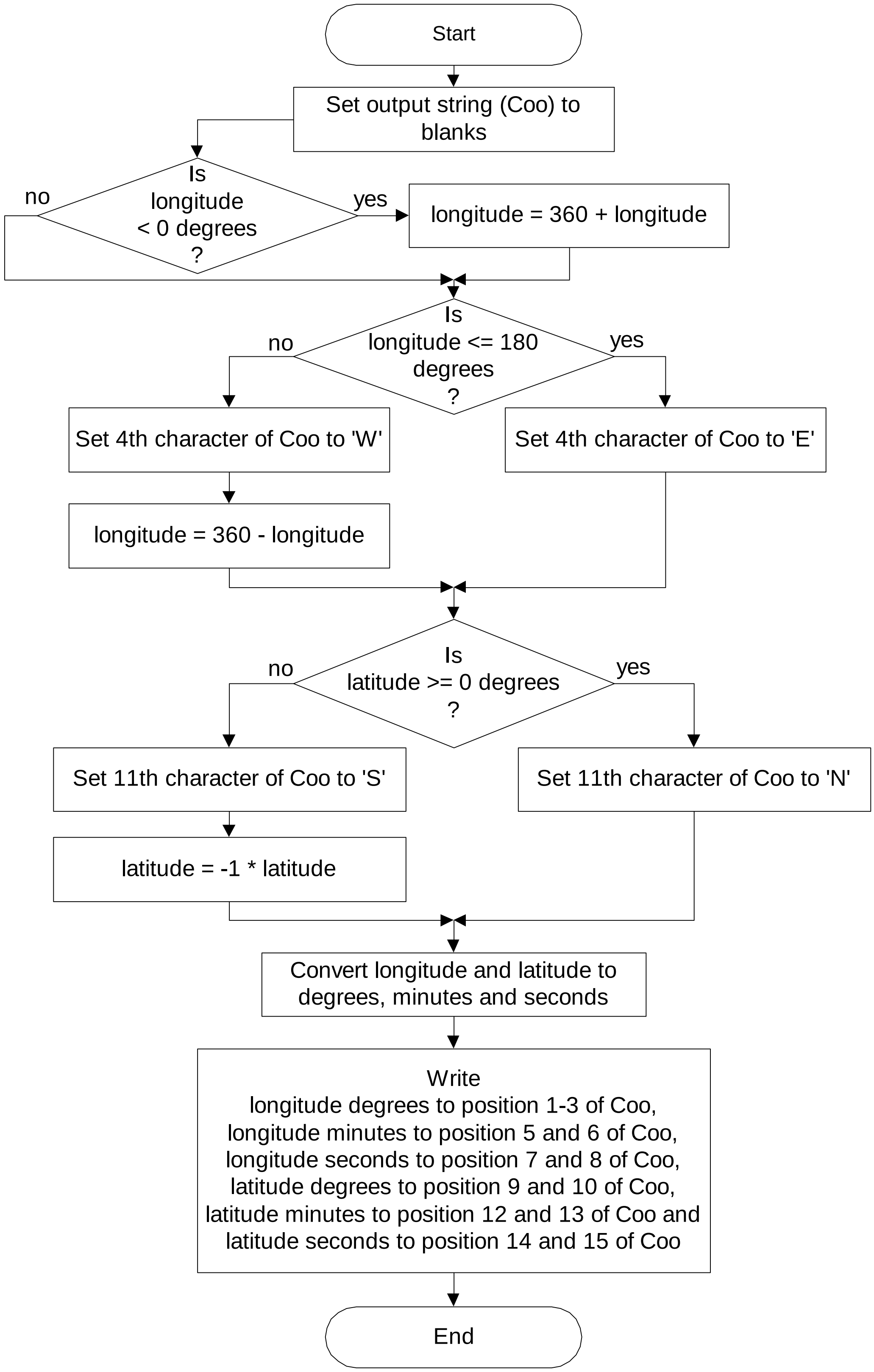
Chapter 5.7: Subroutine Antenna_Correction



Chapter 5.7 Subroutine Antenna_Correction

This process determines the total loss of an antenna in a given three-dimensional direction as fully described in the Annex 8A of the HCM Agreement.

Chapter 5.8: Subroutine CooConv

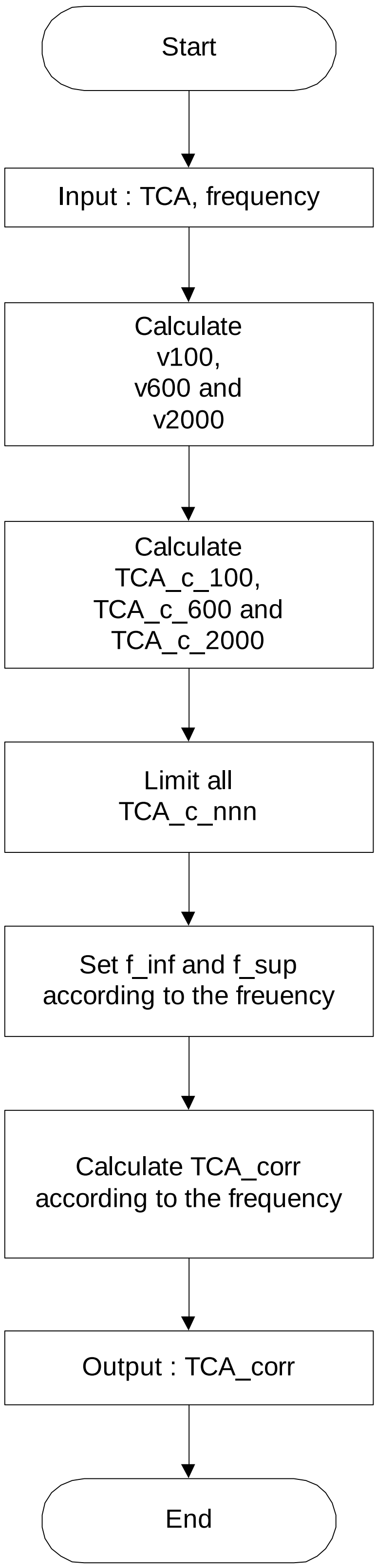


Chapter 5.8 Subroutine CooConv

This process converts co-ordinates from decimal to text format.

The output is in the format ‘111E223344N5500’
where
‘111’ is the longitude degrees
‘E’ is the indicator for East, for West is ‘W’
‘22’ is the longitude minutes
‘33’ is the longitude seconds
‘44’ is the latitude degrees
‘N’ is the indicator for North, for South it is ‘S’
‘55’ is the latitude minutes
‘00’ is the latitude seconds

Chapter 5.9: Subroutine TCA_correction_calculation



Chapter 5.9 Subroutine TCA_correction_calculation

This process calculates the correction factor according to the terrain clearance angle (TCA).

Calculate v100, v600 and v2000

v100 = 0.649 * TCA
v600 = 1.592 * TCA
v2000 = 2.915 * TCA

Calculate TCA_c_100, TCA_c_600 and TCA_c_2000

$$TCA\_c\_100 = 9.1 - (6.9 + 20 * Log(\sqrt{((v100 - 0.1)^2 + 1)} + v100 - 0.1))$$

$$TCA\_c\_600 = 13.1 - (6.9 + 20 * Log(\sqrt{((v600 - 0.1)^2 + 1)} + v600 - 0.1))$$

$$TCA\_c\_2000 = 17.3 - (6.9 + 20 * Log(\sqrt{((v2000 - 0.1)^2 + 1)} + v2000 - 0.1))$$

Limit TCA_c_nnn

Limits:	TCA_c_100	= range from 0 to - 32
	TCA_c_600	= range from 0 to - 35
	TCA_c_2000	= range from 0 to - 36

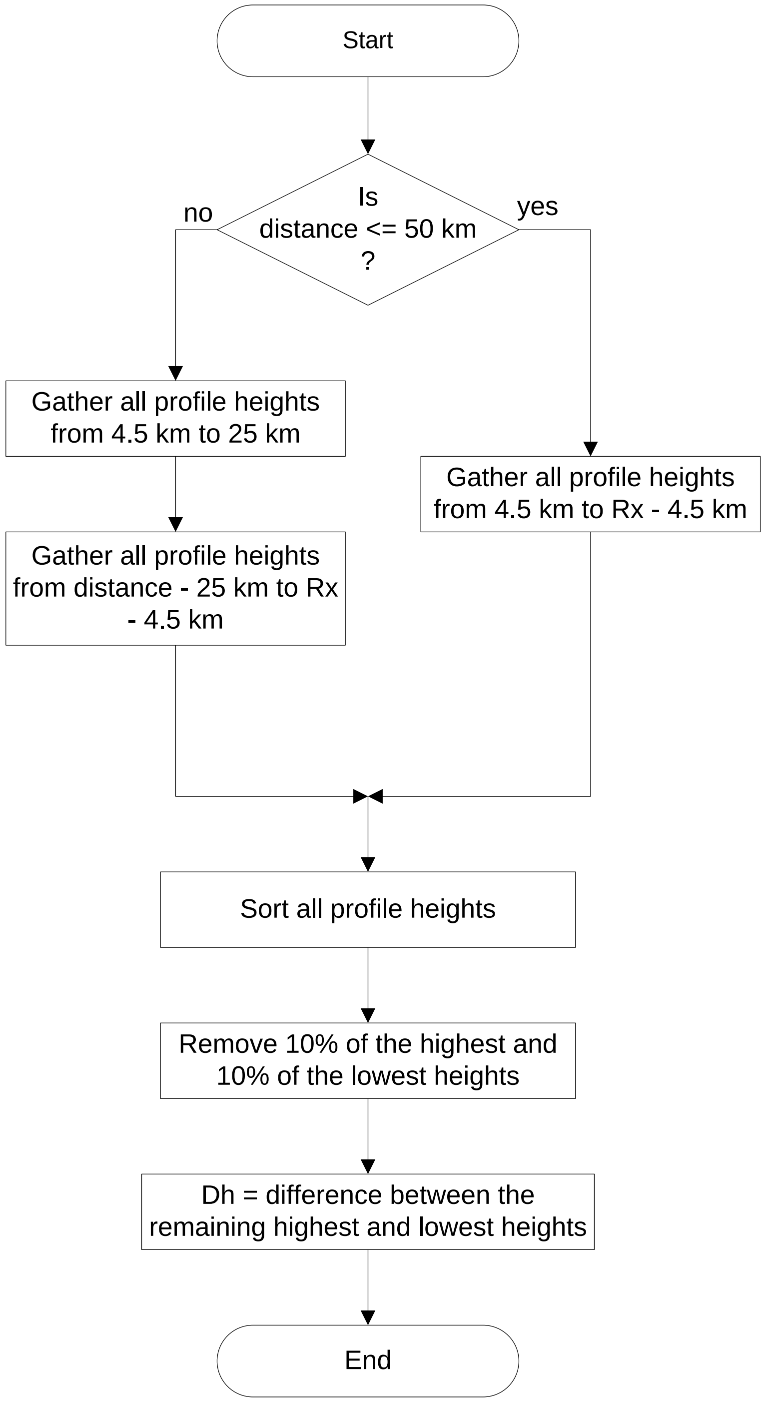
Set f_inf and f_sup according to the frequency

The nominal frequencies f_inf and f_sup (100, 600 or 2000 MHz) are set according to the frequency.

Calculate TCA_corr according to the frequency

The total correction factor TCA_corr is calculated using formulas in Annex 5.

Chapter 5.10: Subroutine Dh_calculation



Chapter 5.10 Subroutine Dh_calculation

This process calculates the terrain irregularity Dh.

Is distance <= 50 km?

If the distance is less than or equal to 50 km, then the profile of the total distance minus two times 4.5 km (at the beginning and at the end) is determined, else two parts of the profile are taken, first at the Tx site from 4.5 to 20 km and second at the Rx site 4.5 km from the Rx to 25 km from the Rx (in direction to the Tx).

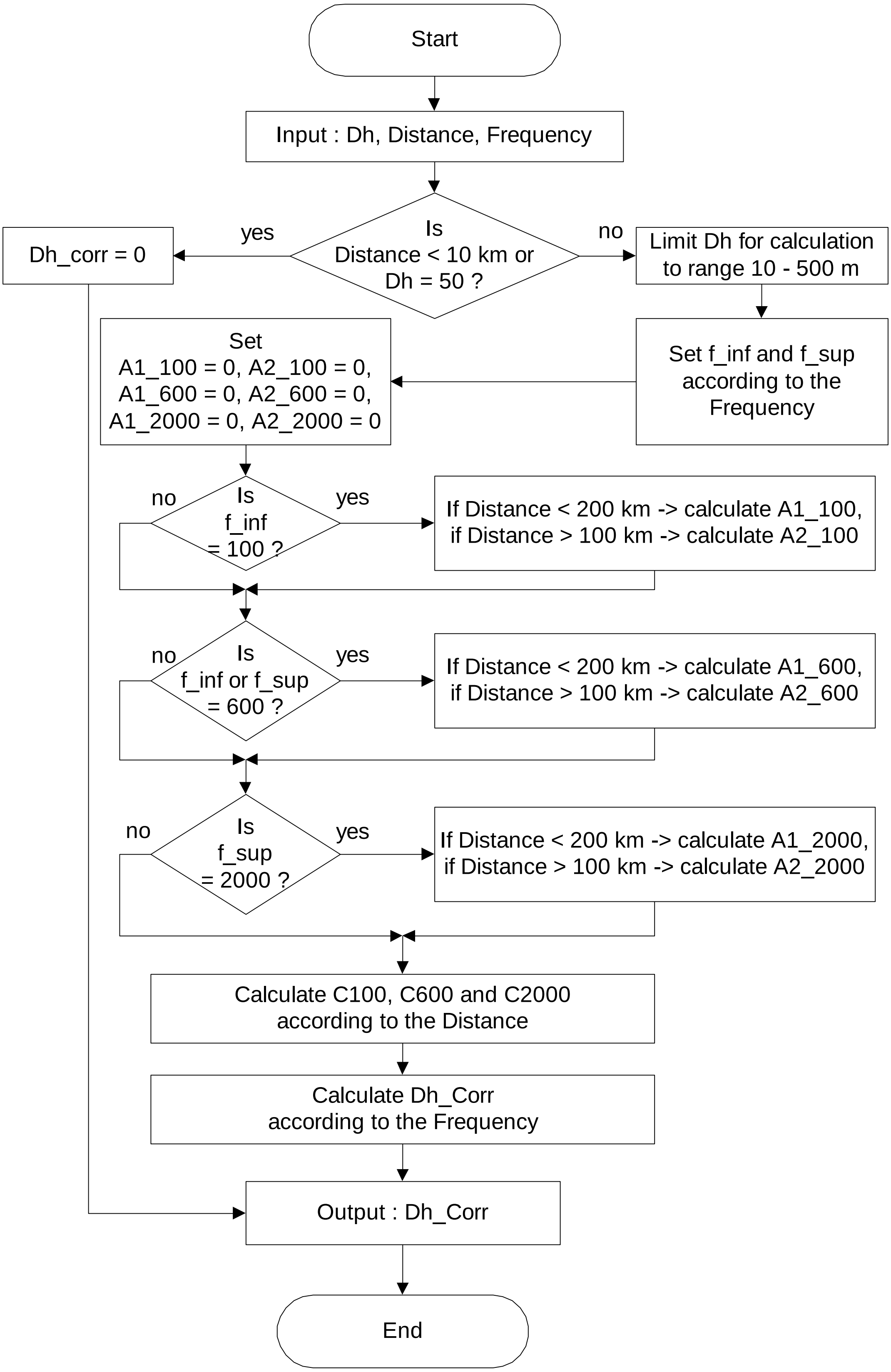
Sort all profile heights

All taken heights are sorted.

Remove 10% of the highest and 10% of the lowest heights

If e.g. 100 heights are taken and sorted, the 10 (=10%) first and 10 last heights are not mentioned and the remaining difference between the lowest and highest heights is the terrain irregularity Dh.

Chapter 5.11: Subroutine Dh_Correction



Chapter 5.11 Subroutine Dh_Correction

This process calculates the correction factor according to the terrain irregularity Dh.

Limit Dh for calculation to range 10 – 500 m

Only for the calculation process, Dh is limited to the range 10 – 500 m.

Set f_inf and f_sup according to the Frequency

The values of f_inf and f_sup are set to one of the nominal frequencies 100, 600 or 2000 MHz according to the Frequency.

According to the values of f_inf and f_sup and the distance, the intermediate values of A1_100, A2_100, A1_600, A2_600, A1_2000 and A2_2000 are calculated.

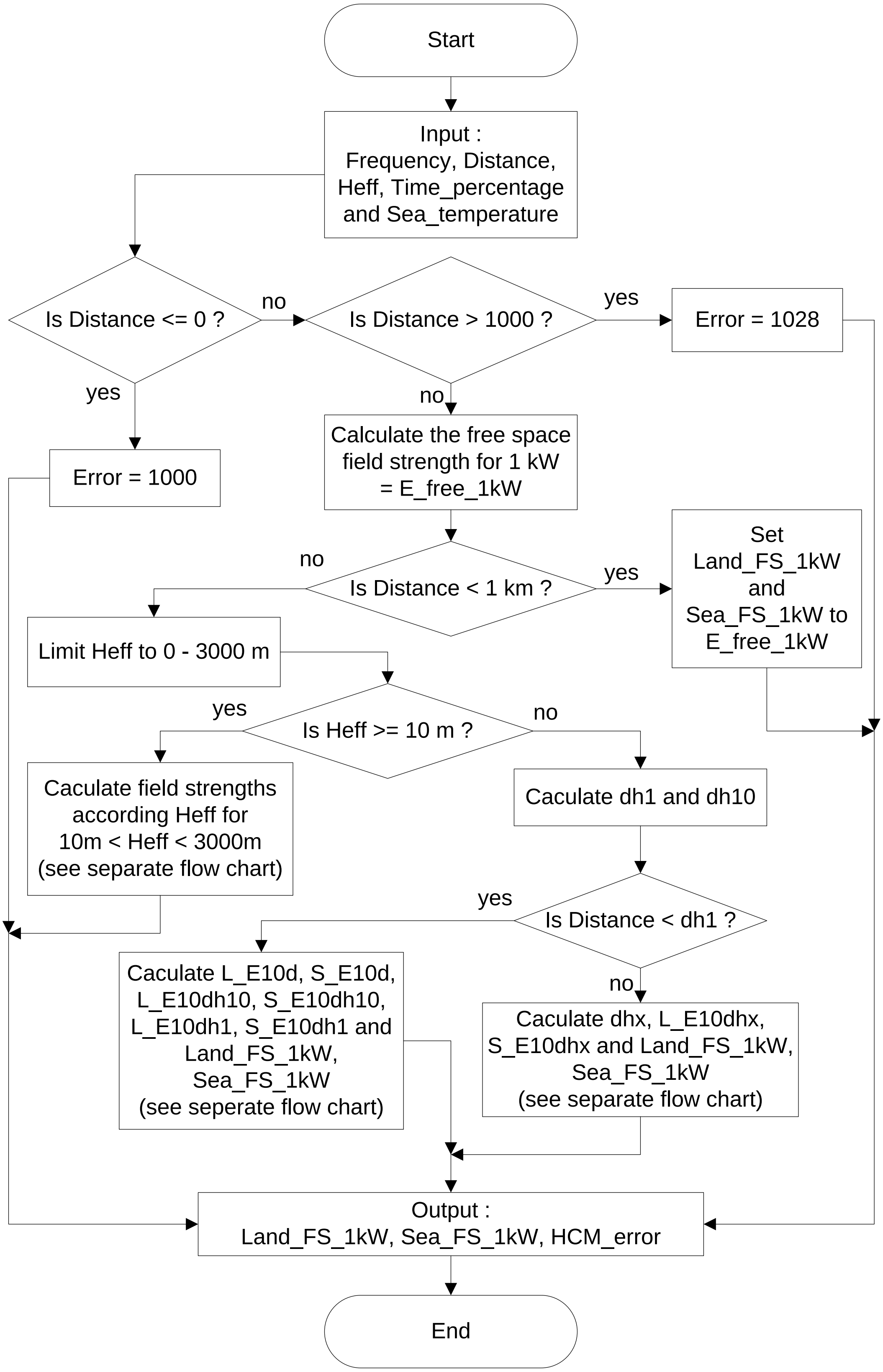
Calculate C100, C600 and C2000 according to the Distance

The correction factors for 100, 600 and 2000MHz (C100, C600 and C2000) are calculated for the correct distance.

Calculate Dh_Corr according to the Frequency

Finally, the correction factor according to the terrain irregularity is calculated for the correct frequency.

Chapter 5.12: Subroutine Get_FS_from_figures



Chapter 5.12 Subroutine Get_FS_from_figures

This process calculates the land- and sea field strength for 1 kW from the figures.

In a first step, the distance is checked if it is greater than 0 and maximum 1000 km. If not, the respective error codes are set and the process terminates.

Calculate the free Space field strength for 1 kW = E_free_1kW

The free space field strength for 1 kW is calculated. This value is required for further steps.

Is Distance < 1 km?

If the distance is less than 1 km, then the land- and sea field strength for 1 kW are set to the free space field strength for 1 kW.

Calculate field strength according Heff for 10 m < Heff < 3000 m (see separate flow chart)

This process calculates the 1 kW field strength for Heff greater than or equal to 10 m and is described in chapter 5.12.1.

Calculate dh1 and dh10

The distances dh1 and dh10 are calculated using formulas of Appendix 2 to Annex 5, chapter 1.2.

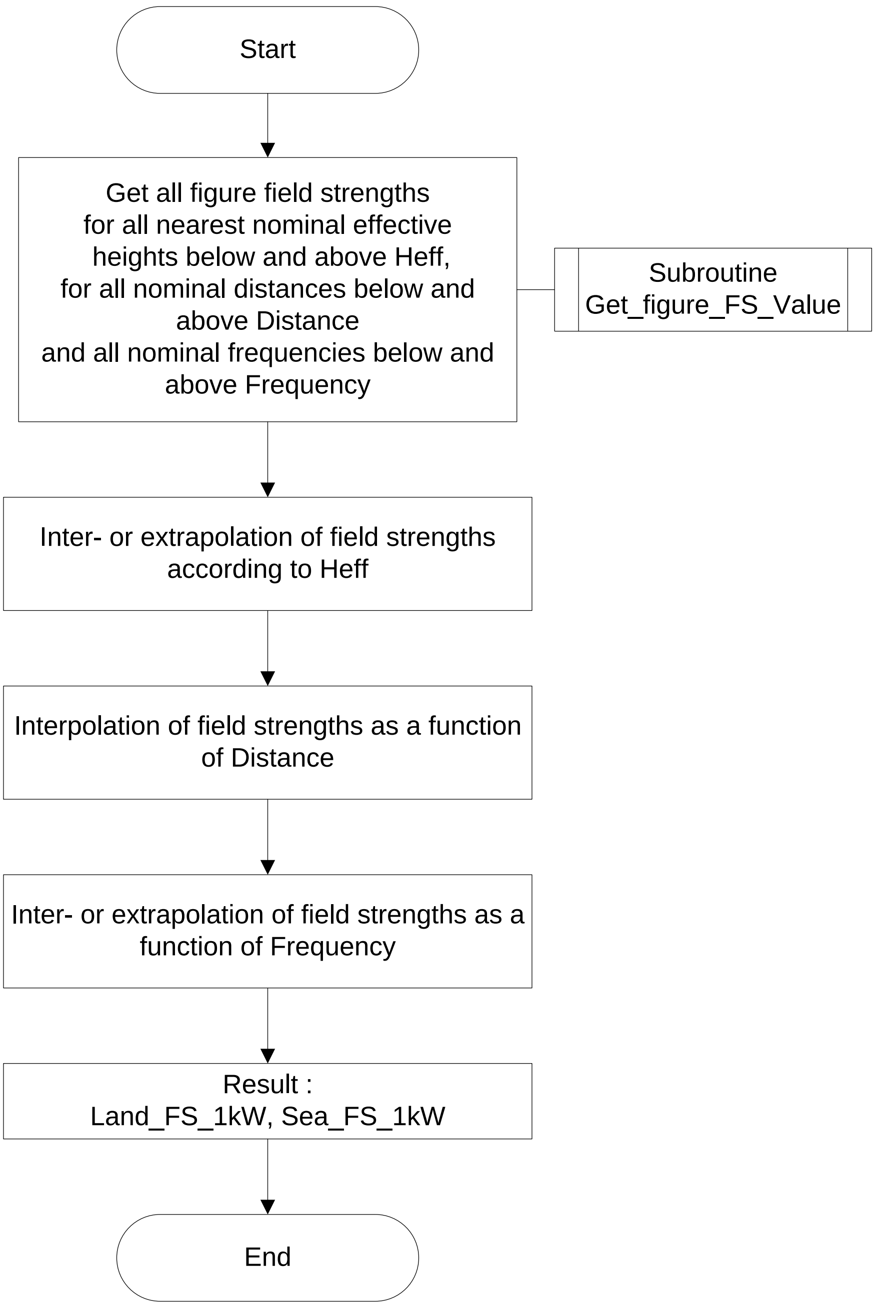
Calculate L_E10d, S_E10d, L_Edh10, S_Edh10, L_E10dh1, S_E10dh1 and Land_FS_1kW, Sea_FS_1kW (see separate flow chart)

If the distance is less than dh1, then the land- and sea field strengths for 1 kW are calculated using this process. This process is described in chapter 5.12.2.

Calculate dhx, L_E10dhx, S_E10dhx and Land_FS_1kW, Sea_FS_1kW (see separate flow chart)

If the distance is equal or greater than dh1, then the land- and sea field strengths for 1 kW are calculated using this process. This process is described in chapter 5.12.3.

Chapter 5.12.1: Caculate field strengths according Heff for 10m < Heff < 3000m



Chapter 5.12.1 Subroutine Get_FS_from_figures
Calculate field strengths according Heff for 10m < Heff < 3000m

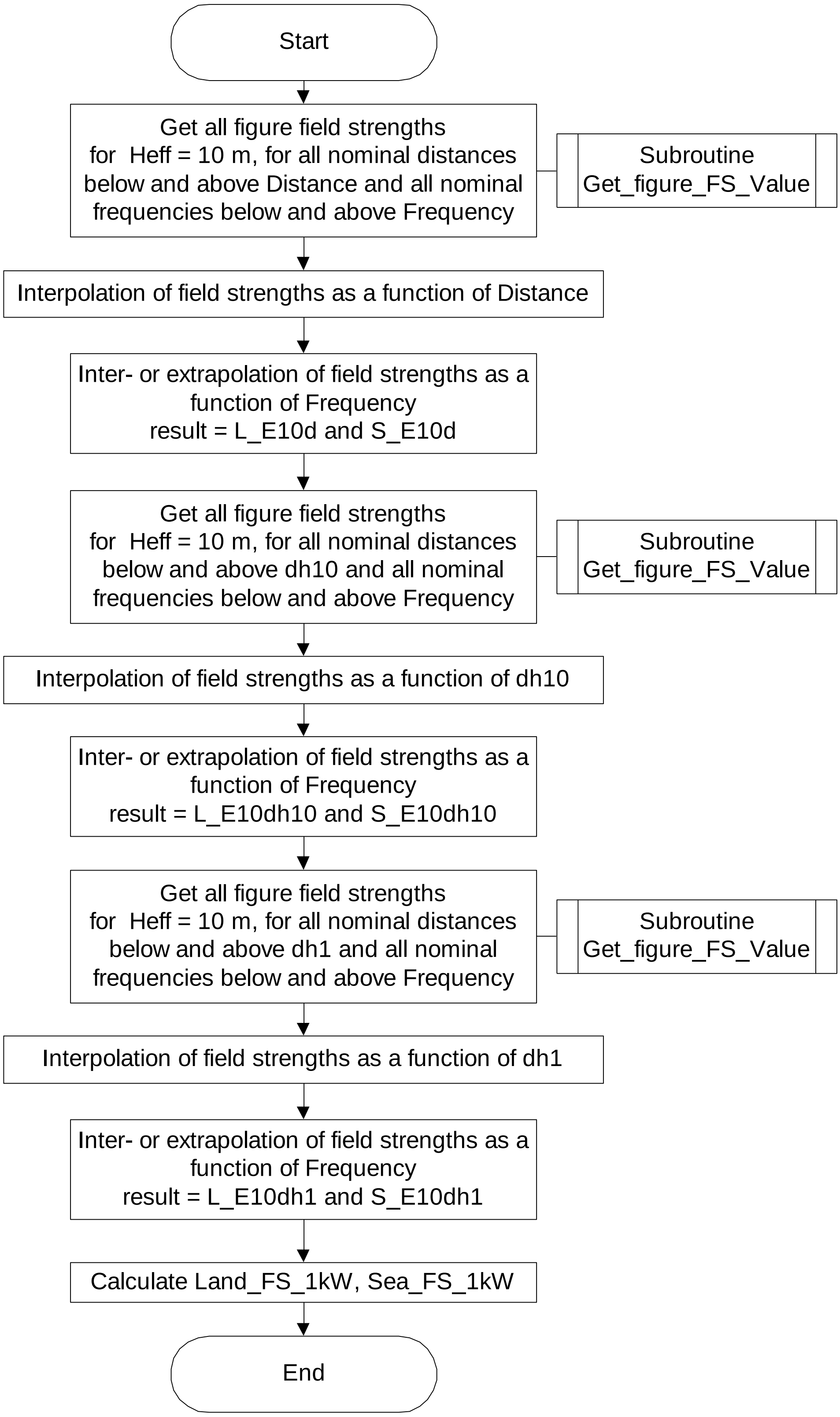
This process calculates the land- and sea field strength for 1 kW from the figures if Heff is between 10 and 3000 m.

Subroutine Get_figure_FS_Value

This process determines the figure values and is described in chapter 5.13.

All the values are interpolated using formulas of Annex 5. The result is the land- and sea field strength for 1 kW.

Chapter 5.12.2: Caculate L_E10d, S_E10d, L_E10dh10, S_E10dh10, L_E10dh1, S_E10dh1 and Land_FS_1kW, Sea_FS_1kW



Chapter 5.12.2 Subroutine Get_FS_from_figures
Calculate L_E10d, S_E10d, L_E10dh10, S_E10dh10, L_E10dh1, S_E10dh1 and Land_FS_1kW, Sea_FS_1kW

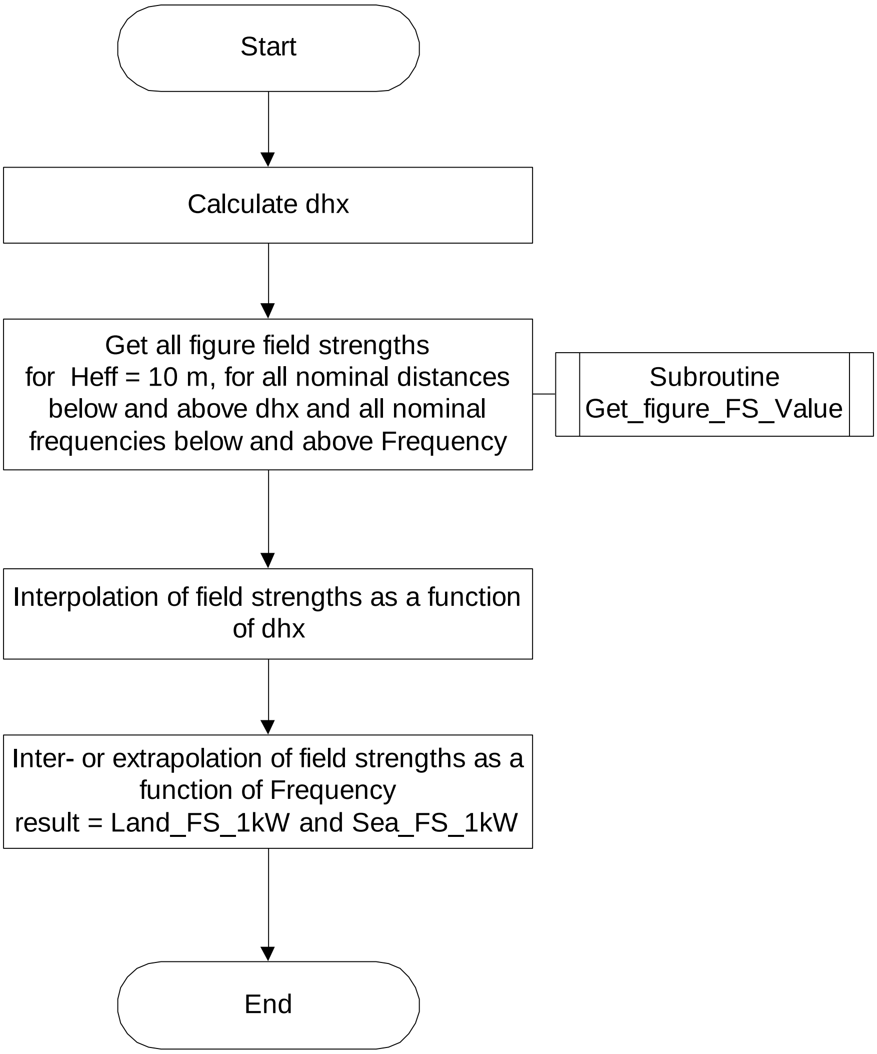
This process calculates the land- and sea field strength for 1 kW from the figures if Heff is less than 10 m and the distance is less than dh1.

Subroutine Get_figure_FS_Value

This process determines the figure values and is described in chapter 5.13.

The whole calculation is based on the formulas of Appendix 2 to Annex 5, chapters 1.2, 2 and 3. The outcome is the land- and sea field strength for 1 kW.

Chapter 5.12.3: Caculate dhx, L_E10dhx, S_E10dhx
and Land_FS_1kW, Sea_FS_1kW



Chapter 5.12.3 Subroutine Get_FS_from_figures
Calculate dhx, L_E10dhx, S_E10dhx and Land_FS_1kW, Sea_FS_1kW

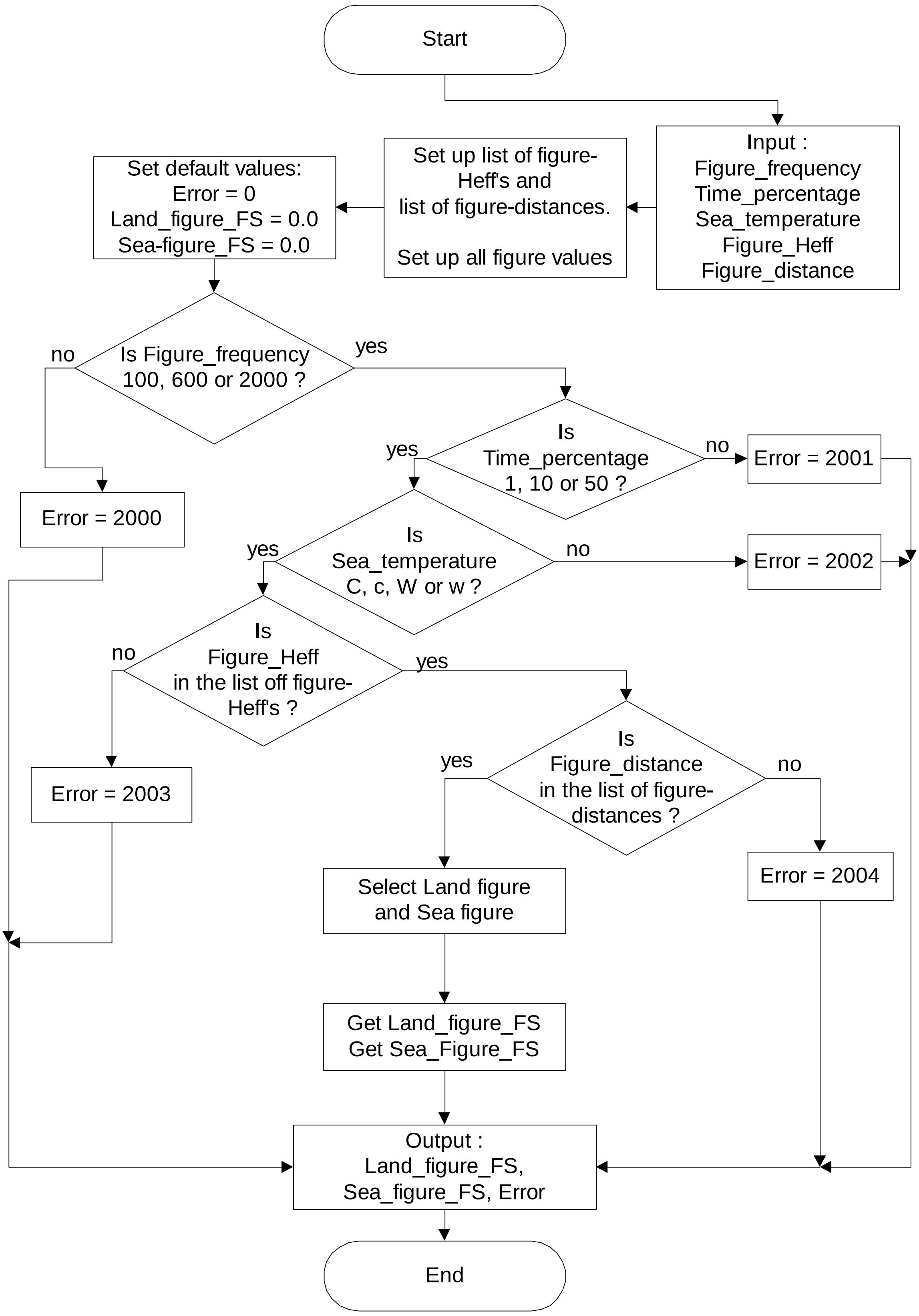
This process calculates the land- and sea field strength for 1 kW from the figures if Heff is less than 10 m and the distance is equal or greater than dh1.

Subroutine Get_figure_FS_Value

This process determines the figure values and is described in chapter 5.13.

The whole calculation is based on the formulas of Appendix 2 to Annex 5, chapters 1.2, 2 and 3. The outcome is the land- and sea field strength for 1 kW.

Chapter 5.13: Subroutine Get_figure_FS_value



Chapter 5.13 Subroutine Get_figure_FS_value

This process gets one figure value for the land field strength and one for the sea field strength from the field strength curves.

The field strength values are stored for the following distances (km):

1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15,
16, 17, 18, 19, 20, 25, 30, 35, 40, 45, 50, 55, 60,
65, 70, 75, 80, 85, 90, 95, 100, 110, 120, 130, 140,
150, 160, 170, 180, 190, 200, 225, 250, 275, 300,
325, 350, 375, 400, 425, 450, 475, 500, 525, 550,
575, 600, 625, 650, 675, 700, 725, 750, 775, 800,
825, 850, 875, 900, 925, 950, 975, 1000

For each distance, the field strength values for the following effective antenna heights are stored:

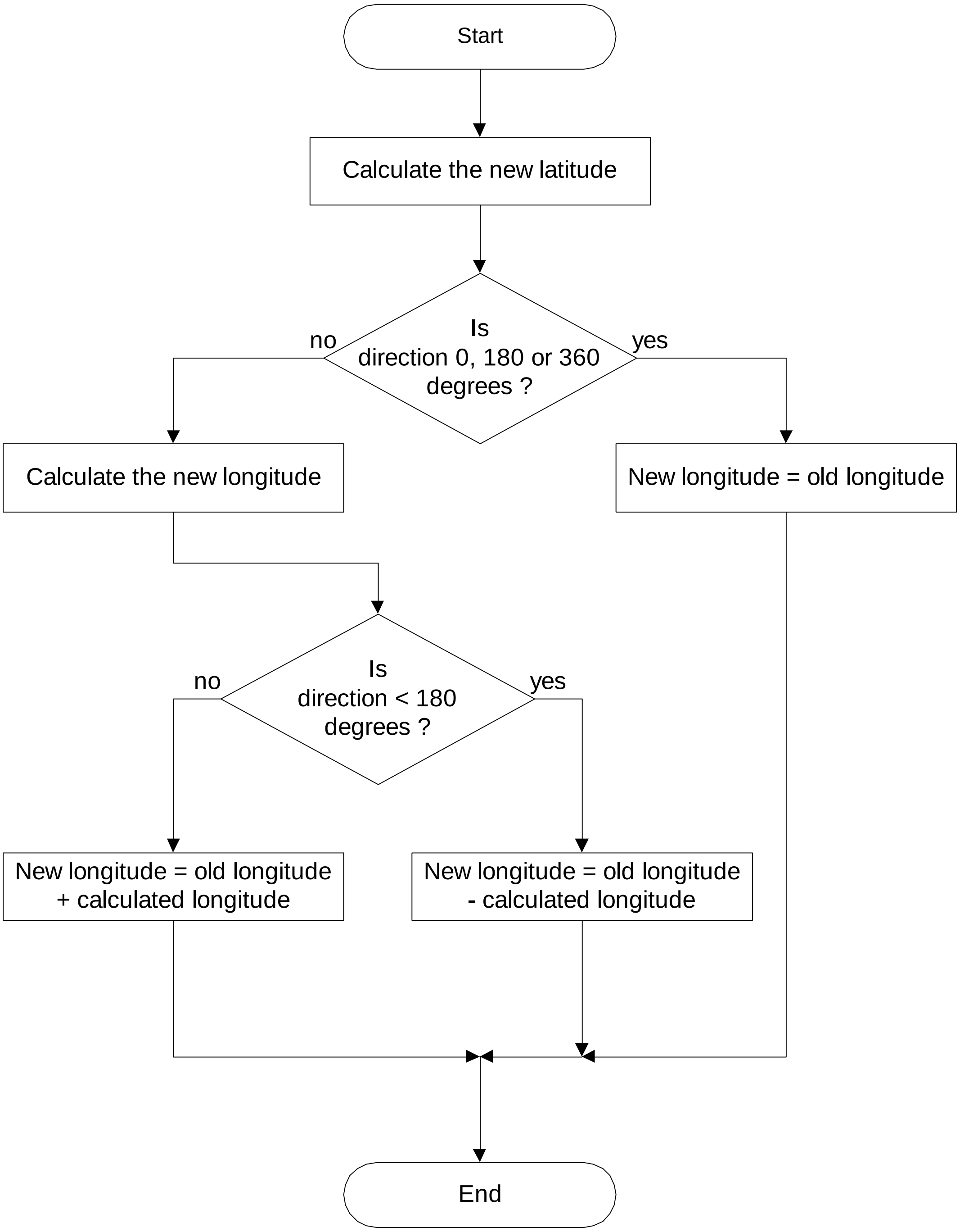
10, 20, 37.5, 75, 150, 300, 600, 1200 m and the maximum field strength (for 1kW).

All this values are stored for the frequencies 100, 600 and 2000 MHz and for time percentages 1, 10 and 50%.

For the sea field strength there are two sets of data, one for cold sea and one for warm sea.

In this process, the selection of the required data elements is done taking into account the frequency, the time percentage, the sea temperature, the effective antenna height and the distance.

Chapter 5.14: Subroutine New_coordinates



Chapter 5.14 Subroutine New_coordinates

This process calculates the new co-ordinates starting from the co-ordinates of a known point going into the known direction with a known distance.

Chapter 6: Storage format of the height data

The height data used by the HCM programs (Mobile Service and Fixed Service) may come from different sources.

Some data may come from military source (Digital Terrain Elevation Data (DTED) Level 1 Coverage); some data are may come from national geographic institutes.

A fallback possibility to get terrain height data is to use GTOPO30 data. This data is free available at the Internet, but it only has a resolution of 30 seconds (approximately 1 km). GTOPO30 data converted to the HCM format are available at the Internet site of the HCM Agreement (http://hcm.bundesnetzagentur.de).

A second fallback possibility is to use the SRTM3 topo data, converted to HCM format. This data has a resolution of 3 seconds by 3 seconds but is only available for latitudes from 61S to 61N. This data is measured from the space and therefor all heights are not the heights above sea level, but the heights include the morphology (e.g. heights of buildings, forests, …). This data is also available on the Internet site of the HCM Agreement.

The HCM terrain height data has a resolution of 3 seconds in the North - South direction and 3 or 6 seconds in the East – West direction (depending on the latitude). If the latitude is less than 50 degrees (North or South), the resolution is 3 seconds, if the latitude is greater or equal to 50 degrees, the resolution is 6 seconds.

All source data has to be converted to WGS84 format and to the above-mentioned resolution. Data from different sources needs to be combined to a common database covering all HCM Agreement Signatory countries (plus an additional range of approximately 100 km).

The storage format of this data is:

- All elevation data consists of 2 Bytes Integer-values (Fixed Binary integers). If the elevation value is negative, first the MSB (Bit #15) has to be cleared and second the complement has to be built to get the correct elevation value.

- Terrain data of a 5 x 5 minute square (approximately 9 x 5 km) is combined in one data-record. Strips in the North and East are added to the data inside the square. The reason is: If you want to have the elevation of a given point, in most cases this point is located between 4 points in the grid of the stored data. To get the correct elevation, you have to interpolate between these 4 points. The western and southern grid-points are always present (example: wanted point 8 degrees 0 minute 1 second → record 8 degrees 0 minute to 5 minutes is read; so the western grid-point (= 8 degrees 0 minute 0 second) is present. In the case where the wanted point is for example 8 degrees 4 minutes 59 seconds, the eastern grid-point is 8 degrees 5 minutes 0 second. Normally this point is not inside the read record, but part of another record (8 degrees 5 minutes to 10 minutes). To prevent the program from reading an additional record, the strip 5 minutes 0 second is added to the record 0 minute to 5 minutes. For the same reason, a strip in the North is also added. It is therefore possible to get the right elevation of a wanted point reading only one record of data.

- 12 x 12 records (=144 records; =1 x 1 degree) are stored in one file.

- The filename is (example): E007N50.63E

where	E007	=	Longitude of the South-West corner,
	N50	=	Latitude of the South-West corner,
	63	=	Resolution in seconds longitude (6) and latitude (3) and
	E	=	Elevation data (M for morphological data)

- Position of records inside the file:

North

	133	134	135	136	137	138	139	140	141	142	143	144	
	121											132	
	109											120	
	97											108	
	85											96	
	73											84	
West	61											72	East
	49											60	
	37											48	
	25											36	
	13											24	
	1	2	3	4	5	6	7	8	9	10	11	12	

South

- All files with the same longitude are stored in the same subdirectory. The name of the subdirectory is equal to the first four characters of the filename (example: E007).

- All subdirectories are stored in the (top level) directory, e.g. 'TOPO'. A valid filename with the full path therefore is:

C:\TOPO\E010\E010N45.33E

Note: in older versions of the HCM software, only the drive letter 'C' may be replaced by any other valid drive letter and the top level directory is fixed to 'TOPO'. In version 7 of the HCM software, it is possible to define the path of the topo-data and only the name of the subdirectory and the file name is fixed, but the old system still works alternatively.

- In Europe, a 5 minutes x 5 minutes square contains north of 50 degrees latitude 101 x 51 values = 5.151 values and south of 50 degrees latitude 101 x 101 values = 10.201 values. One value = 2 Bytes. The length of data records therefore is 10.302 or 20.402 Bytes.

- Record description:
  Length: fixed, 10.302 or 20.402 Bytes
  No carriage control!

- The elevation data inside the record is combined from East to West and from South to North.

Example: (South of 50 degrees latitude, resolution in East-West-direction = 3 seconds; number of elevation data)

North

West

10101	10102	10103			10200	10201
10000	10001	10002			10099	10100
102	103	104			201	202
1	2	3			100	101

East

South

Chapter 7: Storage format of the morphological data

The morphological data required for the HCM programs is provided by the TWG HCM SWG Program (Technical Working Group Harmonized Calculation Method Sub Working Group Program) and is available at the Internet site of the HCM Agreement (http://hcm.bundesnetzagentur.de).

The data is elaborated using GTOPO30 data (see Chapter 6).

The morphological database is a raster database with the same grid and structure as the terrain height database (see Chapter 6).

Each entry consists of two bytes, one for the predominant height of the surface (trees, buildings) and one for the class of the morphology information.

Because each grid point represents an area of 3 x 3 (3 x 6) seconds, more than one class of morphology is possible, e.g. a part is buildings, an other part is trees. In those cases there are different heights for this area. It is possible, to define more than one class, but only one height.

The height information is one byte. Therefore it is possible to define heights from 0 m to 255 m. The height is the predominant height of the area represented by this grid point, e.g. if there are 70 % buildings with 10 m height, 20% trees with 12 m height and 10% roads with 0 m height, 10 m is taken to represent this area.

The class of morphology consists of one byte. Therefore 8 different classes (bits) are possible. For the fixed service land, sea and coastal area are required, for the mobile service only land and sea are required.

- all bits are 0	normal land
- bit 0 is 1	sea, ocean
- bit 1 is 1	small lake, river, small portions of water (no sea, no ocean!)
- bit 2 is 1	coastal area
- bit 3 is 1	villages, towns (buildings)
- bit 4 is 1	trees
- bits 5 to 7	for future use

In general, a morphological database is not required for all countries applying the HCM software. If there is no sea or coastal area (e.g. Austria, Slovakia), the use of a morphological database is not mandatory.

The morphological database offered by the TWG HCM SWG Program does not have height information (all heights are 0 m). Only the morphological classes ‘normal land’, ‘sea / ocean’ and ‘costal area’ are supplied.

All morphological data consists of 2 bytes. The first byte represents the class of morphology; the second byte is the height information.

Morphological data of a 5 x 5 minutes square (approximate 9 x 5 km) is combined in one data-record.

- 12 * 12 records (=144 records; =1 * 1 degree) are stored in one file.

- The filename is (example): E007N50.63M

where	E007	=	Longitude of the South -West corner,
	N50	=	Latitude of the South -West corner,
	63	=	Resolution in seconds longitude (6) and latitude (3) and
	M	=	Morphological data (E for elevation data)

- Position of records inside the file:

North

133	134	135	136	137	138	139	140	141	142	143	144
121											132
109											120
97											108
85											96
73											84
61											72
49											60
37											48
25											36
13											24
1	2	3	4	5	6	7	8	9	10	11	12

West (left side of table) — East (right side of table)

South

All files with the same longitude are stored in the same subdirectory. The name of the subdirectory is equal to the first four characters of the filename (example: E007).

All subdirectories are stored in the (top level) directory, e.g. ‘MORPHO’. A valid filename with the full path therefore is:

C:\MORPHO\E010\E010N45.33M

Note: in older versions of the HCM software, only the drive letter ‘C’ may be replaced by any other valid drive letter and the top level directory is fixed to ‘MORPHO’. In version 7 of the HCM software, it is possible to define the path of the topo-data and only the name of the subdirectory and the file name is fixed, but the old system still works alternatively.

In Europe, a 5 x 5 minutes square contains north of 50 degrees latitude 101 x 51 values = 5.151 values and south of 50 degrees latitude 101 x 101 values = 10.201 values. One value = 2 bytes. The length of data records therefore is 10.302 or 20.402 bytes.

Record description:
Length: fixed, 10.302 or 20.402 Bytes
No carriage control!

The data inside the record is combined from East to West and from South to North.

Example: (South of 50 degrees latitude, resolution in East-West-direction = 3 seconds; number of morphological data)

North

West / **East**

10101	10102	10103			10200	10201
10000	10001	10002			10099	10100
102	103	104			201	202
1	2	3			100	101

South

Chapter 8: Geographical data requirements for line calculations, field strength predictions and storage format of line-data.

Chapter 8.1: Data requirements

Chapter 8.1.1: The different cases:

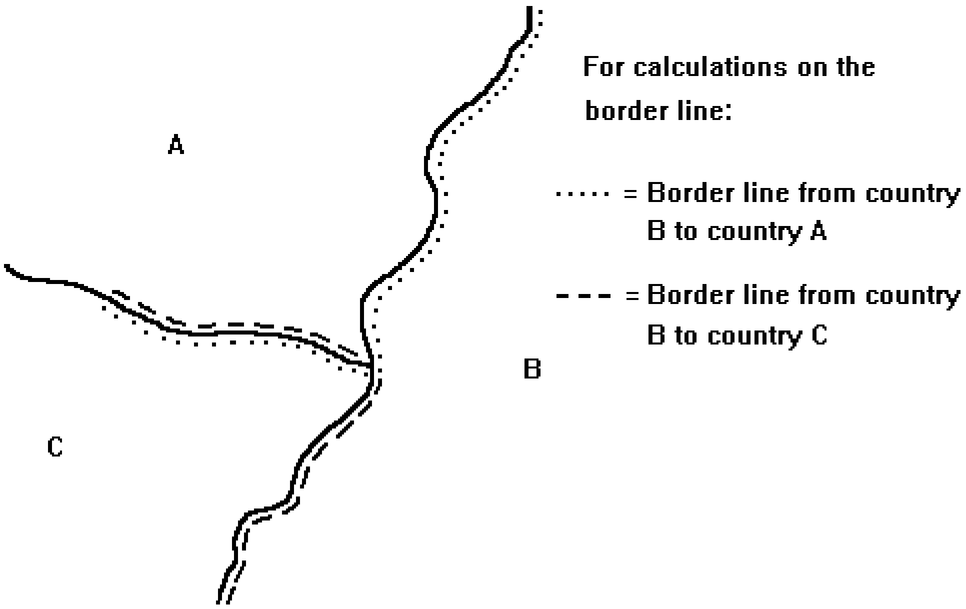
For distance calculations, field strength predictions and calculation of the position of a mobile, following geographical data are required:

⇒ Borderlines to involved countries,
⇒ Cross border lines according to the Annex 1 of the HCM Agreement,
⇒ X-km lines for preferential frequencies (for own and foreign preferential frequencies).
⇒ Closed borderlines of the own and of involved countries (for calculation of the position of mobiles).

These cases are described below.

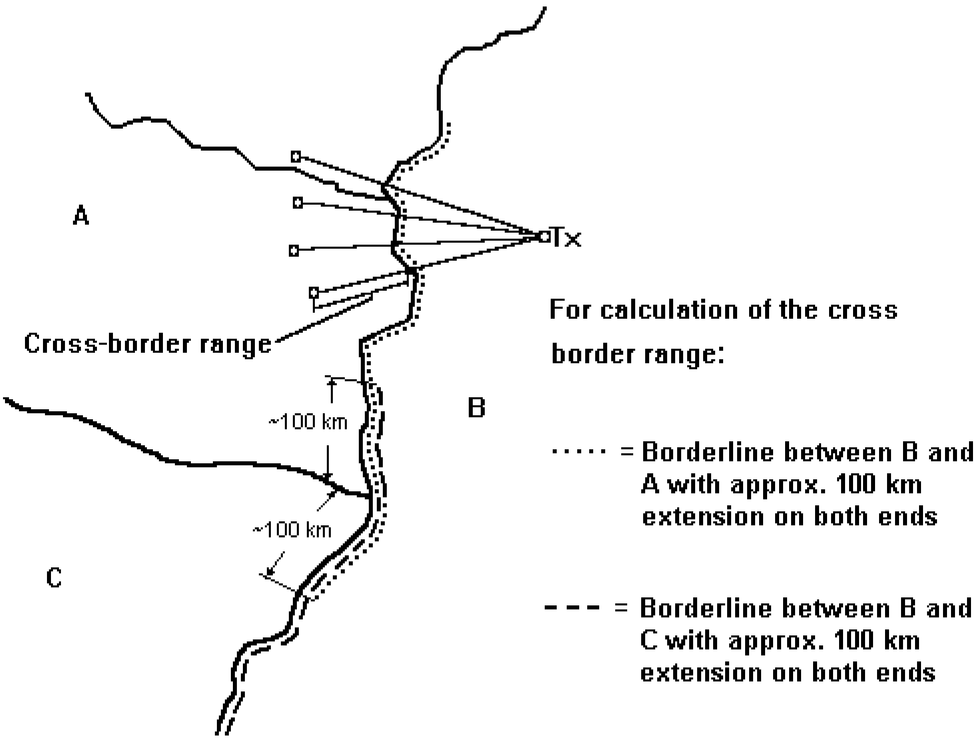
Chapter 8.1.2: Border lines to involved countries:

To determine the necessary borderline for the involved countries, the borderline data of the involved countries are required up to a distance of 100 km within these countries.



Chapter 8.1.3: Cross border lines (cross border ranges):

For calculating the cross border range for Tx the common borderline e.g. between country B and A is used with an extension of approx. 100 km on both ends as shown below.

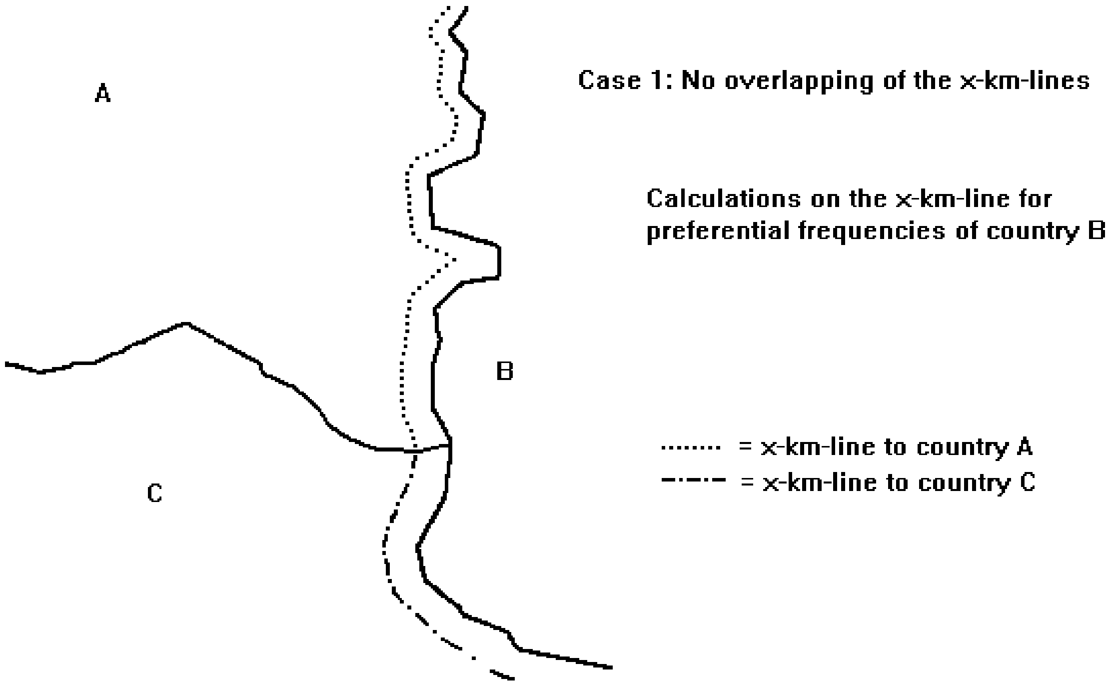


Chapter 8.1.4: x-km lines of preferential frequencies:

To determine the x-km lines in every country involved, the data of these x-km lines with or without an overlap on one or both sides of the border are required. The requirement of an overlap depends on the shape of the borderlines.

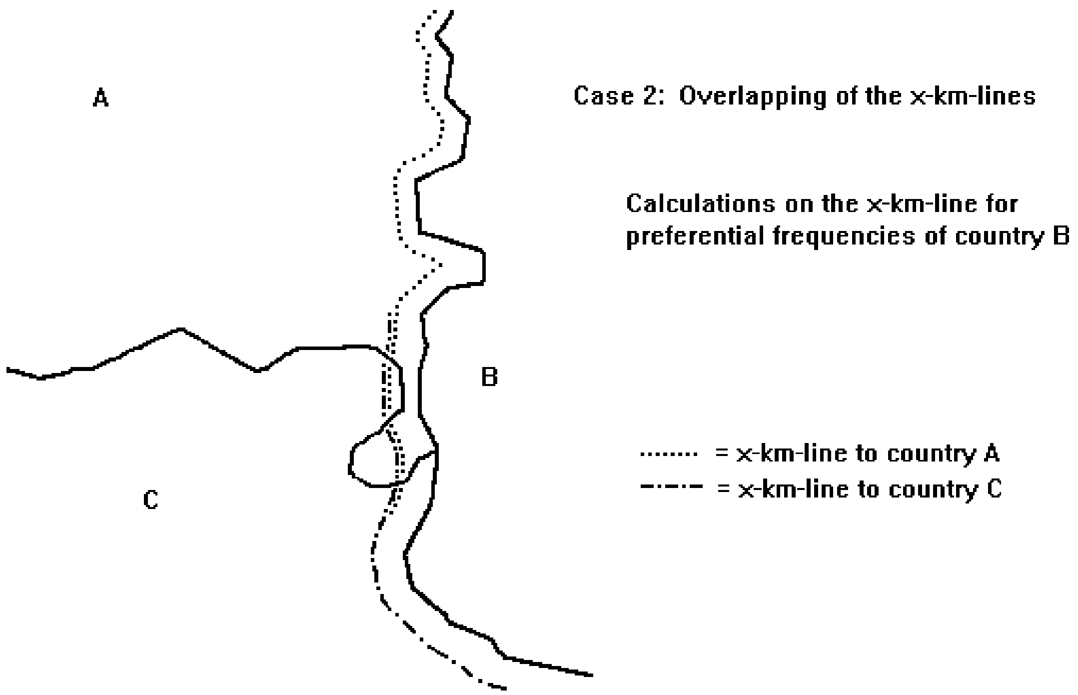
Chapter 8.1.4.1: x-km lines without an overlap:

The normal condition without an overlap is shown in the picture below.



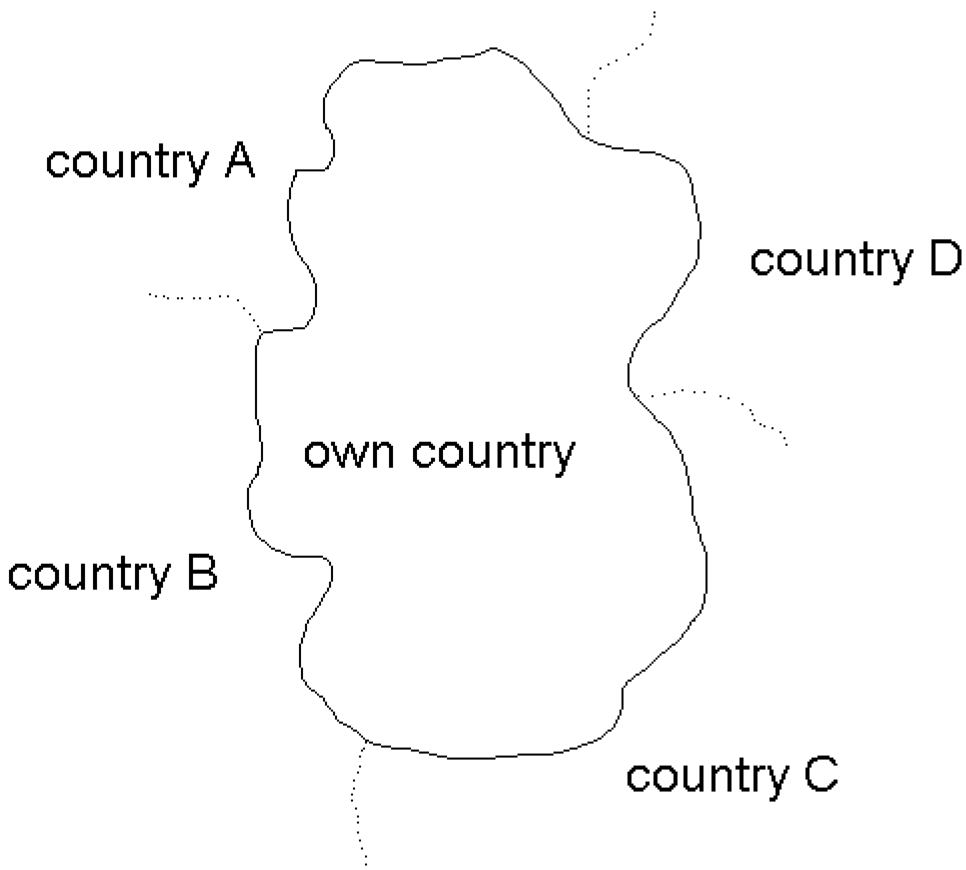
Chapter 8.1.4.2: x-km lines with an overlap:

In some cases, if the borderline e.g. looks like the picture below, an overlap of the x-km-lines is required. How long the overlap is and where the line starts or ends, is subject of a bilateral agreement between the involved countries.



Chapter 8.1.5: Closed borderlines of the own and of involved countries (for calculation of the position of mobiles):

To determine the position of a mobile (if the borderline cuts the service area of this mobile), a closed borderline of the country is required. To obtain a closed borderline the last line point of the file has to be equal to the first line point of the file.



The closed border line of the country is stored in the BORDER directory with the name of the country (country code, 3 characters, missing characters are '_') and the extension 'ALL', e.g. 'HOL.ALL' or 'F__.ALL'

Chapter 8.2: Storage format of the line data:

All line data (borderlines, x-km lines, lines for calculating the cross border range) are stored in different files. The names of those files are build using the two country codes (country from – country to) and the distance to the borderline. If the country code is less than 3 letters, the missing places are filled with underscores (e.g. 'F__'). Borderlines are stored with the extension '.000' (e.g. the borderline between HOL and BEL has the filename 'HOLBEL.000').

Lines to calculate the cross border range use the extension '.CBR'.

Preferential lines (x-km lines) use the value of the distance to the borderline as extension (e.g. '.015' for a 15 km line).

Closed lines to calculate the position of a mobile use the extension '.ALL'.

Line data files consist of fixed length records without carriage control.

To create a record, the co-ordinates of 10 points following each other are selected. The center of these 10 co-ordinates is calculated. This is the 11th point. All co-ordinates are in decimal form, longitude first, latitude second (e.g. 10.14567 45.39876). The result of all 11 points is 22 numbers. These 22 values are converted to radian (value x Π / 180) and stored in REAL x 8 variables. All converted 22 values are stored in one record writing 22 x 8 = 176 Bytes.

Record: long 1, lat 1, long 2, lat 2,…..long 10, lat 10, long11, lat11

Part of a FORTRAN code to store the data (22 radian values of co-ordinates)

```
      PROGRAM TEST
C
      DOUBLE PRECISION   COORD(22)
      CHARACTER*176      LINE
C
      EQUIVALENCE (COORD, LINE)
C
      OPEN (UNIT=1, FILE='HOLBEL.000', ACCESS = 'DIRECT', RECL = 176)
      WRITE (1, REC=1) LINE
C
C     LINE and COORD use the same memory space (EQUIVALENCE statement) !
C
      CLOSE (UNIT=1)
C
      END
```

If for the last record the number of the remaining points is less than 10, the co-ordinates of the last available point is duplicated until 10 co-ordinates are reached.

Chapter 8.3: How to create the required database with the "BORDER" - program:

The "BORDER" program offers the option to create all required data files. As the input for calculations you need the borderline data from your own country, subdivided in portions according to the different involved countries and up to a distance of 100 km from the own border. All data consist of pairs of geographical co-ordinates of border points in decimal, WGS'84 format. It is required as a text file, in each line longitude and latitude of one border point, first longitude, second latitude. These two values have to be delimited by a blank, a comma or a semicolon (see HELP in the BORDER program, example: 9.523 51.324).

For other computers (e.g. UNIX) the BORDER program presents the possibility to store the line data in ASCII-format. This file(s) have to be moved to the other computer and a small program has to be run to convert this data to the format required for the HCM module. This FORTRAN program is listed in paragraph 4.

This BORDER program, with its user guide, is available for free on the Internet site of the HCM Agreement (http://hcm.bundesnetzagentur.de).

Chapter 8.4: FORTRAN program to convert ASCII - line-data to HCM-format:

```
C
C     ASC_BIN.FOR
C
C     Converting ASCII (border-) line data created with the "BORDER"
C     program to binary data.
C
      DOUBLE PRECISION    X(22)
      CHARACTER*176       Y
      CHARACTER*50        IN, OUT
      INTEGER             I, J, IOS, IN_L, OUT_L
C
      EQUIVALENCE (X,Y)
C
C     ************************************************************
C
C     Ask for filenames:
10    WRITE (*,*)
      IN = '                                                  '
      WRITE (*,*) '  Please enter the name of the file containing',
     *            ' the ASCII data:'
      READ (*,'(A50)',END=900,ERR=10) IN
C
20    WRITE (*,*)
      OUT = '                                                  '
      WRITE (*,*) '  Please enter the name of the file for the',
     *            ' binary data:'
      READ (*,'(A50)',END=900,ERR=20) OUT
C
C     Length of filenames:
      IN_L = INDEX (IN, ' ') - 1
      IF (IN_L .LT. 1) GOTO 10
      OUT_L = INDEX (OUT, ' ') - 1
      IF (OUT_L .LT. 1) GOTO 20
C
      OPEN (UNIT=1, FILE=IN(1:IN_L), RECL=440)
      OPEN (UNIT=2, FILE=OUT(1:OUT_L), RECL=176, ACCESS='DIRECT')
C
      J = 1
C
100   READ (1,'(22F20.15)',IOSTAT=IOS) (X(I),I=1,22)
      IF (IOS .EQ. -1) GOTO 900
      IF (IOS .NE. 0) THEN
        WRITE (6,*) ' Error reading ASCII data, I/O-status = ',IOS
        GOTO 900
      END IF
      WRITE (2,REC=J,IOSTAT=IOS) Y
      IF (IOS .NE. 0) THEN
        WRITE (6,*) ' Error writing binary data, I/O-status = ',IOS
        GOTO 900
      END IF
      J = J + 1
      GOTO 100
900   CLOSE (UNIT=1)
      CLOSE (UNIT=2)
      END
```

Chapter 9: Interface to the HCMMS_V7 subroutine in FORTRAN 90.

The HCMMS_V7 program is only a subroutine. To run the program, a surrounding program is required.

The subroutine HCMMS_V7 is written in FORTRAN 90 language (with Compaq Visual Fortran Professional Edition 6.6C). A simple surrounding program is listed below. A more complex surrounding program is supplied by the HCM SWG Program and can be found on the Internet site of the Agreement.

```
!
!     Simple surrounding program for the HCMMS_V7 subroutine.
!
      PROGRAM Test
!
      IMPLICIT   NONE
      INCLUDE    ‘HCM_MS_V7_definitions.f90’
!
!     Prepare all input data
!
      CALL HCMMS_V7
!
!     Show all output data
!
      END PROGRAM Test
!
```

All input- and output data is defined in the file ‘HCM_MS_V7_definitions.f90’. Therefore no arguments are included in the subroutine call.

Description of all input data:

Name	Data type	Description
C_mode	Integer*4	Calculation mode, possible values are: 12 point to point calculation (t%=1%) 11 point to point calculation (t%=50%) 10 point to point calculation (t%=10%) 0 point to point calculation (t%=Channel occ.) -1 point to line calculation (t%=Channel occ., 10m) -9 point to line calculation (t%=10%, 3m) -10 point to line calculation (t%=10%, 10m) -11 point to line calculation (t%=50%, 3m)

More information regarding the several calculation modes are available in the user guide (chapter 6).

		9 UMTS / IMT200 point to point calculation *8 Emergency and security services (380-400Mhz) point to point calculation* *7 normal Agreement coverage calculation (50% time probability)* *6 GSM 1800 – GSM 1800 ML (42 dBµV/m) calculation* *5 GSM 1800 – GSM 1800 FB (38 dBµV/m) calculation* *4 ERMES – ERMES (32 dBµV/m) Calculation* *3 GSM 900 – NMT calculation* *2 GSM 900 –TACS calculation* *1 GSM 900 – GSM calculation* *-2 GSM 900 line calculation (19 dBµV/m, h2=3m)* *-3 ERMES line calculation (12 dBµV/m)* *-4 ERMES line calculation (32 dBµV/m)* *-5 ERMES line calculation (52 dBµV/m)* *-6 GSM 1800 line calculation (25 dBµV/m)* *-7 Emergency and security service (380-400 MHz) line calculation* *-8 UMTS / IMT2000 line calculation*

The values in italic characters are usable only during the transition period.

Coo_Tx	Character*15	Tx co-ordinates, format = ‘015E203052N2040’
Coo_Rx	Character*15	Rx co-ordinates, format = ‘015E203052N2040’ only required if C_mode is 0 or positive
H_Tx_ant	Character*4	Tx antenna height in m
H_Rx_ant	Character*4	Rx antenna height in m, only required if C_mode is 0 or positive
Tx_frequ	Character*12	Tx frequency, format = ‘00147.77000M’
Rx_frequ	Character*12	Rx frequency, format = ‘00147.77000M’, only required if C_mode is 0 or positive
Rad_of_Tx_serv_area	Character*5	Radius of Tx service area
Rad_of_Rx_serv_area	Character*5	Radius of Rx service area, only required if C_mode is 0 or positive

Name	Data type	Description
H_Tx_input	Character*4	Input value of Tx site height (if available)
H_Rx_input	Character*4	Input value of Rx site height (if available) only required if C_mode is 0 or positive
Max_power	Character*6	Maximum radiated power
Type_of_Tx_ant	Character*1	Type of Tx reference antenna (E / I)
Type_of_Rx_ant	Character*1	Type of Rx reference antenna (E / I) only required if C_mode is 0 or positive
Chan_occup	Character*1	Channel occupation (0 /1)
PD	DoublePrecision	Point distance for the profile (default value = 0.1 km)
Perm_FS_input	Character*5	Input value of permissible field strength (if not filled in, the value is taken from the table in Annex 1)
Max_CBR_D_input	Character*3	Input value of maximum cross-border range (if not filled in, the value is taken from the table in Annex 1)
Sea_temperature	Character*1	Sea temperature (C / W)
Topo_path	Character*63	Path of the terrain height data (e.g. 'C:\TOPO')
Morpho_path	Character*63	Path of the morphological data (e.g. 'C:\MORPHO')
Border_path	Character*63	Path of the (border-) line data (e.g. 'C:\BORDER')
D_to_border	Integer*4	Distance to border line (for the selection of the type of line calculation, 0 = calculation on the borderline, negative value = calculation of the maximum cross-border range, positive value x = calculation on the x-km line only required if C_mode is 0 or positive
Land_from	Character*3	Country of Tx or country to calculate from
Land_to	Character*3	Country of Rx or country to calculate to
Rx_ant_gain	Character*4	Gain of Rx antenna only required if C_mode is 0 or positive

Name	Data type	Description
Depol_loss	Character*4	Depolarization loss only required if C_mode is 0 or positive
Cor_fact_frequ_diff	Character*4	Correction factor according to frequency Difference, only required if C_mode is 0 or positive, if missing, this value is calculated
Azi_Tx_input	Character*5	Tx azimuth
Azi_Rx_input	Character*5	Rx azimuth, only required if C_mode is 0 or positive
Ele_Tx_input	Character*5	Tx elevation
Ele_Rx_input	Character*5	Rx elevation, only required if C_mode is 0 or positive
D_sea_input	Character*5	Input value of distance over sea; if filled, the calculation of distance over sea is switched off
Ant_typ_H_Tx	Character*7	Horizontal antenna type of Tx
Ant_typ_V_Tx	Character*7	Vertical antenna type of Tx
Ant_typ_H_Rx	Character*7	Horizontal antenna type of Rx, only required if C_mode is 0 or positive
Ant_typ_V_Rx	Character*7	Vertical antenna type of Rx, only required if C_mode is 0 or positive
Desig_of_Tx_emis	Character*9	Designation of emission of Tx
Desig_of_Rx_emis	Character*9	Designation of emission of Rx, only required If C_mode is 0 or positive

Description of all output data:

Name	Data type	Description
HCM_error	Integer*4	Error value, see list of HCM_error values
Info(i)	Logical*4(20)	List of Info(i) values, see list of Info values
Calculated_FS	Real	Calculated field strength
Perm_FS	Real	Permissible field strength
Prot_margin	Real	Protection margin
Free_space_FS	Real	Free space field strength
Distance	DoublePrecision	Distance between Tx position and Rx position
D_sea_calculated	DoublePrecision	Calculated distance over sea (or from input value)
Dir_Tx_Rx	DoublePrecision	Horizontal direction from Tx to Rx
Dir_Rx_Tx	DoublePrecision	Horizontal direction from Rx to Tx
V_angle_Tx_Rx	DoublePrecision	Vertical direction from Tx to Rx
V_angle_Rx_Tx	DoublePrecision	Vertical direction from Rx to Tx
H_diff_angle_Tx_Rx	DoublePrecision	Horizontal difference angle from Tx to Rx
H_diff_angle_Rx_Tx	DoublePrecision	Horizontal difference angle from Rx to Tx
V_diff_angle_Tx_Rx	DoublePrecision	Vertical difference angle from Tx to Rx
V_diff_angle_Rx_Tx	DoublePrecision	Vertical difference angle from Rx to Tx
Delta_frequency	DoublePrecision	Frequency difference in kHz
Heff_Tx	Real	Tx effective antenna height
Heff_Rx	Real	Rx effective antenna height
Heff	Real	Total effective antenna height
Dh	Real	Terrain irregularity
Dh_corr	Real	Correction factor according to the terrain irregularity

Name	Data type	Description
Tx_TCA	Real	Tx clearance angle
Rx_TCA	Real	Rx clearance angle
Tx_TCA_corr	Real	Correction factor according to the Tx clearance angle
Rx_TCA_corr	Real	Correction factor according to the Rx clearance angle
ERP_ref_Tx	Real	ERP of the reference transmitter
Land_FS	Real	Land field strength
Sea_FS	Real	Sea field strength
Tx_ant_corr	Real	Correction factor according to the Tx antenna type (horizontal and vertical)
Rx_ant_corr	Real	Correction factor according to the Rx antenna type (horizontal and vertical)
Tx_ant_type_corr	Real	Correction factor according to the Tx reference antenna type (E / I)
Rx_ant_type_corr	Real	Correction factor according to the Rx reference antenna type (E / I)
Perm_FS_from_table	Real	Permissible field strength from the Table in Annex 1
Corr_delta_f	Real	Correction factor according to the Frequency difference (calculated or from The input value)
Channel_sp_Tx	Real	Channel spacing of Tx in kHz
Channel_sp_Rx	Real	Channel spacing of Rx in kHz
Power_to_Rx	Real	Power in direction of Rx
CBR_D	Real	Maximum cross-border range in km (from input value or from table in Annex 1)

Name	Data type	Description
Version	Character*5	HCMMS_V7 version number
Coo_Tx_new	Character*15	Calculated Tx co-ordinates
Coo_Rx_new	Character*15	Calculated Rx co-ordinates (or line co-ordinates)
T_Prof(i)	Integer*2(10002)	Terrain height profile
M_Prof(i)	Integer*2(10002)	Morphological profile
PN	Integer*2	Number of profile points
H_Datab_Tx	Integer*2	Tx site height from terrain database
H_Datab_Rx	Integer*2	Rx site height from terrain database

Chapter 10: Interface to the HCMMS_V7.DLL

To simplify the use of the HCM software, the HCM team build a dynamic link library HCMMS_V7.DLL.

A lot of programming languages (e.g. Visual Basic, C++) are able to work with DLL's.

An example in Visual Basic is available from the HCM team.

There are some restrictions in some programming languages: Boolean - and String variables are difficult to handle and the number of arguments is limited. Therefore some modifications in the interface are required:

- No Boolean variables are passed,
- Only one String is passed.

The Interface to (and from) the DLL is:

There is one Subroutine called HCMMS_V7_DLL.

The arguments are:

C_mode
An input value; the mode of calculation; a 4 byte INTEGER (LONG in VB); permissible values = -11 to +12; Values -2 to -8 and 2 to 10 are usable only during the transition period.

Bor_dis
An input value; the distance to the borderline; a 4 byte INTEGER (LONG in VB);
Values: 0 = calculations are performed on the borderline, positive value x = calculations are performed at the x-km line, any negative value = calculation of the maximum cross-border range.

PD
An input value; the distance between two profile points (grid size) in km; an 8 byte DOUBLE PRECISION (DOUBLE in VB); this value has to be set to 0.1 (default value).

Distance
An output value; the distance between transmitter and the receiving point in km; an 8 byte DOUBLE PRECISION (DOUBLE in VB).

H_Datab_Tx
An output value; a 2 byte INTEGER (INTEGER in VB); the height of the transmitter site above sea level from the terrain database in m.

H_Datab_Rx
An output value; a 2 byte INTEGER (INTEGER in VB); the height of the receiver site above sea level from the terrain database in m. This value is only valid if CMODE is positive!

HCM_error
An output value; a 4 byte INTEGER (LONG in VB); the error code. Error codes are listed in the HCM documentation.
An additional error code is generated by the DLL software:
Number: 3000
Description: The string variable passed to the DLL is too short (less than 432 characters).

Heff
An output value; a 4 byte REAL (SINGLE in VB), the effective antenna height in m used for the calculations according the ITU_R method.

Dh
An output value; a 4 byte REAL (SINGLE in VB), the terrain irregularity in m used for the calculations according the ITU_R method.

Dh_corr
An output value; a 4 byte REAL (SINGLE in VB), the correction factor according to the terrain irregularity in dB used for the calculations according the ITU_R method.

Power_to_Rx
An output value; a 4 byte REAL (SINGLE in VB), the power in the direction of the receiver in dBW.

Free_space_FS
An output value; a 4 byte REAL (SINGLE in VB), the free space field strength in dBµV/m.

Land_FS
An output value; a 4 byte REAL (SINGLE in VB), the land field strength in dBµV/m.

Sea_FS
An output value; a 4 byte REAL (SINGLE in VB), the sea field strength in dBµV/m.

Tx_ant_corr
An output value; a 4 byte REAL (SINGLE in VB), the correction factor in dB according to the transmitter antenna type (horizontal and vertcal).

Tx_ant_type_corr
An output value; a 4 byte REAL (SINGLE in VB), the correction factor in dB according to the transmitter antenna type ('E' or 'I').

Dir_Tx_Rx
An output value; a DOUBLE PRECISION (DOUBLE in VB), the horizontal direction from the transmitter to the receiver in degrees.

V_angle_Tx_Rx
An output value; a DOUBLE PRECISION (DOUBLE in VB), the vertical direction from the transmitter to the receiver in degrees.

Tx_TCA
An output value; a 4 byte REAL (SINGLE in VB), the transmitter clearance angle in degrees.

Rx_TCA
An output value; a 4 byte REAL (SINGLE in VB), the receiver clearance angle in degrees.

Tx_TCA_corr
An output value; a 4 byte REAL (SINGLE in VB), the correction factor according to the transmitter clearance angle in dB.

Rx_TCA_corr
An output value; a 4 byte REAL (SINGLE in VB), the correction factor according to the receiver clearance angle in dB.

D_sea_calculated
An output value; a DOUBLE PRECISION (DOUBLE in VB), the distance over sea in km taken into account during the calculations (either input value or calculated value).

Rx_ant_corr
An output value; a 4 byte REAL (SINGLE in VB), the correction factor in dB according to the receiver antenna type (horizontal and vertical).

Rx_ant_type_corr
An output value; a 4 byte REAL (SINGLE in VB), the correction factor in dB according to the receiver antenna type (‘E’ or ‘I’).

Delta_frequency
An output value; a DOUBLE PRECISION (DOUBLE in VB), the frequency difference between transmitter - and receiver frequency in kHz.

Corr_delta_f
An output value; a 4 byte REAL (SINGLE in VB), the correction factor according to the frequency difference between transmitter - and receiver frequency in dB.

Calculated_FS
An output value; a 4 byte REAL (SINGLE in VB), the calculated field strength in dBµV/m.

Perm_FS
An output value; a 4 byte REAL (SINGLE in VB), the permissible field strength in dBµV/m (input value or calculated value).

CBR_D
An output value; a 4 byte REAL (SINGLE in VB), the maximum cross border range in km (input value or from Agreement).

ERP_ref_Tx
An output value; a 4 byte REAL (SINGLE in VB), the power of the reference transmitter in dBW.

Prot_margin
An output value; a 4 byte REAL (SINGLE in VB), the protection margin in dB (difference of calculated field strength and permissible field strength).

I_str

An input / output value (a part of this string is only input, an other part is only output). A CHARACTER (STRING in VB) variable with at least 432 characters. The content of this string is:

Start position	Stop position	Description	In-/ Output	Format
1	15	Tx co-ordinates	Input	009E223350N4422
16	30	Rx co-ordinates	Input	009E223350N4422
31	34	Height of Tx site	Input	9999 or four blanks
35	38	Height of Rx site	Input	9999 or four blanks
39	45	Tx hor. ant. Type	Input	000ND00
46	52	Tx vert. ant. type	Input	000ND00
53	57	Tx Azimuth	Input	999.9
58	62	Tx Elevation	Input	+99.9
63	66	Tx Antenna height	Input	9999
67	70	Rx Antenna Height	Input	9999
71	71	Tx Type of antenna	Input	'E' or 'I'
72	77	Max. radiated power	Input	+999.9
78	89	Tx Frequency	Input	99999.99999M
90	90	Channel occupation	Input	'0' or '1'
91	91	Sea temperature	Input	'C' or 'W'
92	96	Tx Service area	Input	99999
97	101	Rx Service area	Input	99999
102	106	Distance over sea	Input	99999 or 5 blanks
107	118	Rx Frequency	Input	99999.99999M
119	127	Rx Design. of emis.	Input	14k0.....
128	136	Tx Design. of emis.	Input	14k0.....
137	143	Rx hor. ant. Type	Input	000ND00
144	150	Rx vert. ant. Type	Input	000ND00
151	155	Rx Azimuth	Input	999.9
156	160	Rx Elevation	Input	+99.9
161	161	Rx Type of ant.	Input	'E' or 'I'
162	165	Rx Antenna gain	Input	99.9
166	169	Depolarisation loss	Input	99.9
170	174	Perm. Field strength	Input	+99.9 or 5 blanks
175	178	Corr. fact. acc. freq. diff.	Input	99.9 or four blanks
179	181	County code to calcul. to	Input	XXX
182	184	County code of Tx	Input	XXX
185	187	Max. cross border range	Input	999 or 3 blanks
188	250	Path of terrain data	Input	C:\TOPO..... (63 C)
251	313	Path of borderline data	Input	C:\BORDER (63 C)
314	376	Path of morphological data	Input	C:\MORPHO (63 C)
377	382	Version number	Output	
383	402	Info values (field, 20 values)	Output	'T'rue or 'F'alse
403	417	Tx co-ordinates calculated	Output	008E213651N2137
418	432	Rx co-ordinates calculated	Output	007E413672N4127
433	???	Debug directory (optional)	Input	e.g. 'C:\Temp'

Note:

If more than 432 characters are passed, the remaining part (> 432) must be a valid directory name.

If a valid directory is given, the HCMMS_V7_DLL will write a text-file into this directory:
DEBUG.TXT every time it is called.

DEBUG.TXT contains all input values passed to the DLL and stores all output values coming from the DLL.

Additional files

To run the DLL on your system, you need some additional run-time files.

The self-installing executable kit ‘VFRUN66CI.exe’ installs the run-time components needed to run Visual Fortran applications on systems, which do not have Visual Fortran, installed.

The components installed by this kit are:

- DFORRT.DLL - Visual Fortran non-threaded run-time support
- DFORMD.DLL - Visual Fortran threaded run-time support
- FQWIN.HLP - QuickWin run-time help file
- MSVCRT.DLL - Microsoft Visual C run-time support
- OLEAUT32.DLL - Microsoft OLE Automation
- OLEPRO32.DLL - Microsoft OLE Automation
- STDOLE32.TLB - Microsoft OLE Automation

Files will be installed only if newer versions do not exist on the system. The files in this kit can be used with earlier versions of Visual Fortran.

The file ‘VFRUN66CI.exe’ is available on the server.

Annex: List of error codes and Info(i) values.

HCM_error values:

0	No error
36	Error opening terrain- or morphological data file (data not available)
200	Error in longitude (in 'Point_height' or 'Point_type' subroutine)
210	Error in latitude (in 'Point_height' or 'Point_type' subroutine)
220	Error reading record (in 'Point_height' or 'Point_type' subroutine)
300	Latitude is not in range of 0.0 - 90.0 (in 'Point_height' or 'Point_type' subroutine)
400	Height is missing (-9999) (in 'Point_height' subroutine)
1000	Distance between Tx and Rx = 0. Calculations not possible
1001	Error in geographical coordinates (Tx longitude, degrees)
1002	Error in geographical coordinates (Tx longitude, minutes)
1003	Error in geographical coordinates (Tx longitude, seconds)
1004	Error in geographical coordinates (Tx longitude, E/W)
1005	Error in geographical coordinates (Tx latitude, degrees)
1006	Error in geographical coordinates (Tx latitude, minutes)
1007	Error in geographical coordinates (Tx latitude, seconds)
1008	Error in geographical coordinates (Tx latitude, N/S)
1009	Error in Tx antenna height
1010	Error in transmitting frequency value
1011	Error in transmitting frequency unit
1012	Error in radius of service area of Tx
1013	Error in input value height of Tx site above sea level
1014	Error in geographical coordinates (Rx longitude, degrees)
1015	Error in geographical coordinates (Rx longitude, minutes)
1016	Error in geographical coordinates (Rx longitude, seconds)
1017	Error in geographical coordinates (Rx longitude, E/W)
1018	Error in geographical coordinates (Rx latitude, degrees)
1019	Error in geographical coordinates (Rx latitude, minutes)
1020	Error in geographical coordinates (Rx latitude, seconds)
1021	Error in geographical coordinates (Rx latitude, N/S)
1022	Error in Rx antenna height
1023	Error in reception frequency value
1024	Error in reception frequency unit
1025	C_mode is out of range
1026	Error in input value of permissible field strength
1027	Error in input value of maximum cross border range
1028	The distance is greater than 1000 km. Calculations not possible
1029	Error in radius of Rx service area
1030	Error in input value Rx site height above sea level
1031	Error in Tx elevation
1032	Error in Tx azimuth
1033	Error in type of Tx antenna (E/I)
1034	Error in power
1035	Error in input value of distance over sea
1036	The 'xxx.ALL' borderline file for Tx is missing
1037	The 'xxx.ALL' borderline file for Rx is missing

1038	Error in type of antenna
1039	Error in input data of correction factor according frequency difference
1040	Channel spacing outside definition range (Rx)
1041	Channel spacing outside definition range (Tx)
1042	Error in Rx elevation
1043	Error in Rx azimuth
1044	Error in Rx type of antenna ("E" or "I")
1045	Error in gain of Rx antenna
1046	Error in input data of depolarization loss
1047	Distance to borderline is too long
1048	Selected line data not available
1049	Error in line data
1050	No HCM Agreement frequency and important technical data is missing e.g. CBR, max. perm. FS

2000	wrong Figure_frequency	(from Get_figure_FS_value)
2001	wrong Time_percentage	(from Get_figure_FS_value)
2002	wrong Sea_temperature	(from Get_figure_FS_value)
2003	wrong Figure_Heff	(from Get_figure_FS_value)
2004	wrong Figure_distance	(from Get_figure_FS_value)

3000 DLL inputstring to short

Info(i) values:

1	No height of Tx site is given or Tx is mobile; height is taken from the terrain database
2	Height of Tx site differs from height of terrain database
3	Height of Tx site differs more than 10%, calculated values may be (extremely) wrong!
4	Frequency out of range of table in Annex 1
5	Input value of permissible field strength is used
6	Input value of maximum cross border range is used
7	Distance between Tx and Rx is less than both service area radiuses; field strength is set to 999.9
8	No height of Rx site is given or Rx is mobile/line, height is from the terrain database
9	Height of Rx site differs from height of terrain data
10	Rx site height differs more than 10%, calculated values may be (extremely) wrong!
11	Free space field strength used because distance < 1km
12	Free space field strength is used, because 1st Fresnel zone is free
13	Distance over sea is greater than total distance. Distance between Tx and Rx is used!
14	Input value of correction factor according frequency difference is used
15	Frequency difference outside definition range; 82 dB is used
16	Calculated distance over sea is set to 0 because of missing morphological data.
17	Tx channel spacing outside definition range, 25 kHz is used!
18	Correction factors for the band 380 - 400 MHz are used.