10 CALCULATIONS: F+ FREQUENCY ASSIGNMENT

10.1 INTRODUCTION

The Frequency Assignment tool assigns frequencies to stations, considering any restrictions imposed by existing assignments using general methods for all services.

The Frequency Assignment function provides these general possibilities:

- Assignment of frequencies for stations in exclusive allocations, with no restrictions imposed by existing assignments.
- Assignment of new frequencies in existing allocations, where present assignments must be considered.
- Assignment of simplex and duplex frequencies.
- Selection of certain strategies to control the selection of frequencies across the available band or discrete frequencies.
- Full range of propagation models available for different evaluation purposes and assignment strategies.
- Consideration to the cross-polarisation discrimination between the wanted signal and the interfering signals due to the antenna properties and the propagation medium. Normal/Orthogonal polarisation can be assigned automatically, considering the polarisation properties of the selected allotment.

The frequency assignment procedure usually starts with establishing which existing assignments that must be considered. All stations in the current project are considered in the assignment process, but assignment is only executed for the stations that are specifically marked in the project. Available frequencies are defined in user-defined frequency allotments, i.e. frequency channelling plans. Many different frequency channelling plans (the term used in WRAP is **allotment**) are standardised on a national or international basis. The user enters applicable allotments into WRAPdB. It is also possible to exclude frequencies in allotments to prevent assignment of these.

When stations and an allotment are defined the program calculates a transmission loss matrix that defines all the transmission losses between the stations involved in the assignment process. These values are used in the subsequent process to calculate the wanted signal levels and the interfering signal levels. The transmitter spectrum, receiver selectivity and antenna diagrams are taken into account. Any external transmitter filters and receiver filters are also included in the calculations. Any propagation model can be used to calculate the loss matrix between each pair of stations.

For area coverage services the mobiles are located at the edge of the service area as close to the interfering station as possible, if the received signal level at this point is at least equal to the receiver sensitivity. Otherwise the placement is iterated to find the maximum communication range within the service area. When a service area is not defined the mobiles are placed at the maximum range as defined by the uplink or downlink power budget and the receiver sensitivities, also as close to the interfering station as possible. Additional requirements for placing the mobiles are defined by entering the minimum distance between a mobile and the interfering base, and the minimum distance between interfering mobiles. These requirements constitute limiting conditions when coverage areas are overlapping. When using detailed terrain models for propagation calculations there could be a risk of positioning the mobiles at locations outside the contiguous, primary coverage area, due to enhancements in signal strength on hills far away. This risk is reduced to an insignificant level in most practical cases by a method that converges on placing of the mobiles at the edge of the contiguous, primary coverage area.

For all stations with directional antennas the following applies: Test points are established on the connecting line to other stations for stations that are within the 6 dB forward lobe width of the station antenna. If the other station is outside the 6 dB lobe the test point is placed on the line of the nearest 6 dB lobe limit.

For sector stations in multi-point stations and cells in cellular base stations the following applies: Test points for the mobiles between sector stations and cells within the same MP station/base station for area-covering multi-point and cellular base stations are placed at the -3 dB point on the antenna forward lobe at the range limit, alternatively on the service area limit (the smallest of the two). The iteration to find the range limit starts at the maximum free-space range for the link budget of the sector/cell and mobile station.

An alternative placement method of the mobiles is by identifying the best server point between each pair of stations. For the case of overlapping coverage areas this results in placing the mobile at the point where the received signal level is equal from both stations in the pair. In this case the entry of minimum base-to-mobile distance is not available.

The mobiles can be defined to be at constant height above sea.

For fixed services the locations of the stations are given by the station coordinates.

The **semi-manual** assignment strategy in WRAP is based on an interactive approach. The semi-manual method provides a list of stations to be assigned frequencies, together with the available frequencies and the restrictions for each available frequency. The user selects one new frequency for one of the stations. WRAP calculates restrictions imposed by the new assignment, and presents a new list. This is performed until frequencies have been assigned to all stations. Step-back is possible to change assignments that may be needed if the procedure results in a poor assignment.

In addition, there is always a graphical display of the status for each frequency. The display indicates the negative of the assignment margin, in dB, for the marked station at each frequency in the allotment. The assignment margin of a frequency and station is defined as the minimum of the following three expressions

$$\left.\frac{S}{I}\right|_{calculated} - \left.\frac{S}{I}\right|_{required} - PM \quad (1)$$

for the marked station and PM is a user defined protection margin

$$S_{calculated} - S_{sensitivity} \quad (2)$$

for the marked station

$$\min\left\{\left.\frac{S}{I}\right|_{calculated} - \left.\frac{S}{I}\right|_{required} - PM\right\} \quad (3)$$

for all stations where I is the interference power radiated from the marked station and PM is a user defined protection margin.

In some cases a fourth expression is also used. This expression handles the absolute level of the interference signal

$$I_{threshold} - I_{calculated} \quad (4)$$

where $I_{threshold}$ is a user defined maximum level of the interference signal and $I_{calculated}$ is the interference power on adjacent channels.

If the first expression is lower than zero then the signal-to-interference ratio of the station to be assigned is too small to be acceptable. If the second expression is lower than zero the wanted signal is lower than the sensitivity (plus protection margin) of the receiver and hence communication is impossible. The third expression means that if the signal-to-interference ratio that the station to be assigned produces at any other station is lower than the required signal-to-interference ratio (plus protection margin) at the other station, then assignment is not possible. That is, the interference power from the station to be assigned is too high to be acceptable.

The fourth expression is used if the user checks the "**Allowed interference on adjacent channels**" box. **Figure 10.4** shows the "Settings" dialogue. The maximum interference power on adjacent channels can then be defined. The power from all transmitters with a frequency separation greater than or equal to a user defined frequency separation is summed. The sum is then compared to the maximum allowed value according to (4) above.

When the station to be assigned is a station in a link, both the station of concern and the other station in the link are tested according to the expressions above. The display then shows the minimum assignment margin of the station of concern and the other station in the link.

For area-covering services where the coverage areas for different base stations are overlapping other base stations there is a potential for the mobiles to be very close to an interfering base station. The minimum distance between a mobile and an interfering base can be defined in order to have control over the close-range interference situation. If this was not done, the *mobile-to-interfering_base* situation would require a very large frequency separation in order to operate properly. This provides the ability to define a geographical protection zone around the base stations. The mobile is placed at this minimum distance from the interfering base, on the connecting line between the bases for the calculation of the downlink *interfering_base-to-mobile* interference and for the calculation of the uplink *mobile-to-base_interference*. $S_{calculated}$ in (2) above is in the case of uplink *interfering_mobile-to-base* interference set to the receiver sensitivity, $S_{sensitivity}$. Note again that these conditions are only used for the case of coverage areas for different base stations overlapping other base stations. When using the best server placement method the entry of minimum base-to-mobile distance is not available.

The case of mobile-to-mobile interference when coverage areas are overlapping is handled in a similar way. The minimum mobile-to-mobile distance can be specified, and this distance is used to calculate the transmission loss between the mobiles and subsequently the interference from one mobile's transmitter to the other mobile's receiver and reverse. The mobiles are placed on the connecting line between the bases at the nearest point to their own respective base. This is to establish the downlink interference in a mobile generated from other mobiles. $S_{calculated}$ in formula (2) is in the case of downlink interfering_mobile-to-mobile interference set to the receiver sensitivity, $S_{sensitivity}$

In area coverage services there are in total 8 interference cases to test for each Base/Mobile pair:

- Base 1 transmitter to Base 2 mobile; Base 2 mobile to Base 1 receiver
- Base 2 transmitter to Base 1 mobile; Base 1 mobile to Base 2 receiver
- Base 1 transmitter to Base 2 receiver; Base 2 transmitter to Base 1 receiver
- Base 1 mobile to Base 2 mobile; Base 2 mobile to Base 1 mobile. This is assumed to be a symmetrical case since the mobiles are identical.

The display shows the minimum assignment margin of these 8 cases.

The interference is considered according to the following conditions when establishing the blocking:

- The station to be assigned a frequency is considered as the only interferer to all the other receivers. This may in some cases result in a condition of blocking when all stations have been assigned. It can be handled by defining an additional protection margin if this situation is displayed in the result.
- The power sum of the interference from all the other stations at the receiver of the station to be assigned a frequency is considered.

For digital links the required signal-to-interference ratio is replaced by the maximum threshold-to-interference ratio (T/I). The sensitivity ($S_{sensitivity}$) is replaced by the maximum of the two corresponding (for BER 10^{-3} and 10^{-6}) threshold values, (T).

A colour code is used to indicate whether the frequency is considered blocked or assignable:

- Red: Assignment margin negative, i.e. the calculated signal-to-interference ratio is too small, or the wanted signal is too low or the station interferes too much
- Blue: Already used by the station to be assigned
- Yellow: Free to assign

The **automatic** method uses a graph-colouring algorithm where the algorithm attempts to assign frequencies optimally. The criteria to determine if frequencies are assignable are the same as for the semi-manual method. Several strategies in the station and frequency order of assignment are available. The methods are described in [**A23**].

The stations are sorted in one of the following ways:

- Smallest last, SL. The transmitter with the smallest restriction is placed last. The restriction is calculated as the number of transmitters that blocks the usage of a frequency for the transmitter of interest.
- Generalised smallest last, GSL. As above, but the restrictions are calculated as the total number of frequencies blocked for the transmitter of interest.
- Random. The order of the stations in the list is random. This gives a new frequency assignment result every time the assignment is performed. Note that this method does not give a very efficient frequency utilisation.

Assignment is then performed in the following priority orders:

- ST, Sequential technique. The stations are assigned in the order according to the priority list.
- AF, Available frequencies. The station, which has the smallest number of frequencies available, is assigned first.

Frequencies may be assigned in the following order:

- Smallest acceptable, SA. Assigns the first acceptable frequency from either band edge.
- Smallest Most Heavily Occupied, SMHO. Assigns the first acceptable frequency that has been assigned to most stations.

It is possible to set a restriction on the minimum separation between frequencies to be automatically assigned to a station. This is useful for instance in cases where combining arrangements in a base station site do not allow the use of adjacent frequencies.

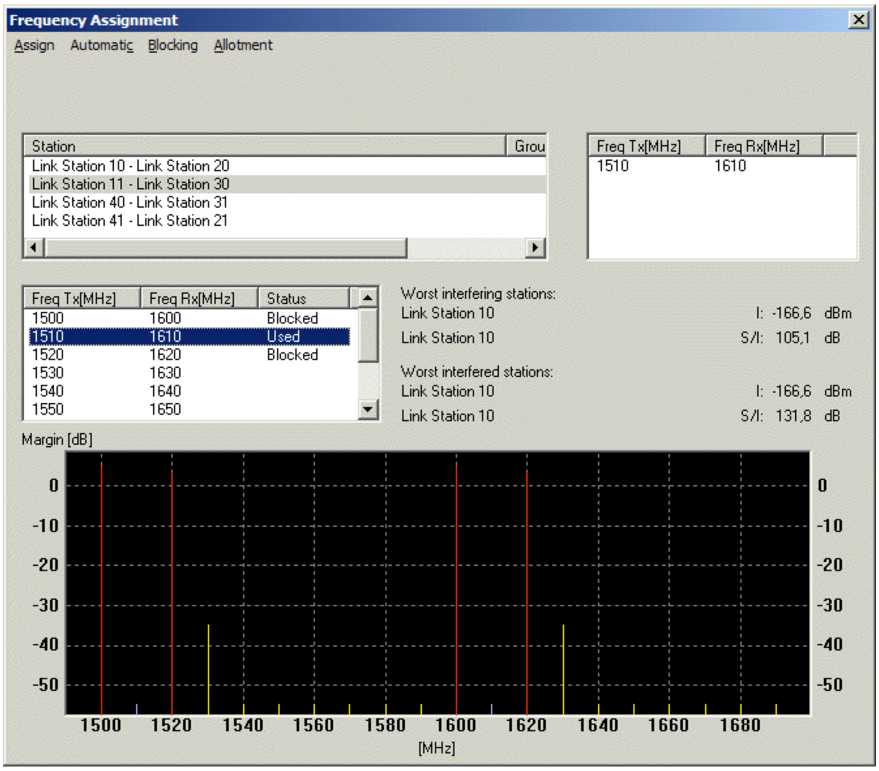


Figure 10.1: *Frequency Assignment tool, main window (1510 MHz assigned).*

The evaluation of the interference situation is done for both the normal and the orthogonal polarisation for the case of automatic assignment when the mode for *Assign polarisation* has been selected. The assignment then is performed with the highest priority to attempt to assign the same frequency with orthogonal polarisation. If this can not be performed the next frequency is tested for the normal polarisation, and if assignment can not be achieved, the orthogonal polarisation is tested. Consideration is taken to the polarisation properties of the selected allotment, to be compatible with its polarisation rules (i. e. if the allotment for instance defines *Vertical linear* polarisation on a specific frequency, only this type of polarisation is allowed for that frequency).

Go through the following examples to learn about most of the commands described above:

10.1.1 Example 1A: Semi-manual assignment, 10 MHz link allotment

- Open the project named ***FrequencyAssignment.WPR***.
- Select This Project, Stations in Project. Note the frequencies (assignments) currently in use for the

link stations. This list will later be compared to the saved result at the end of Example 2.

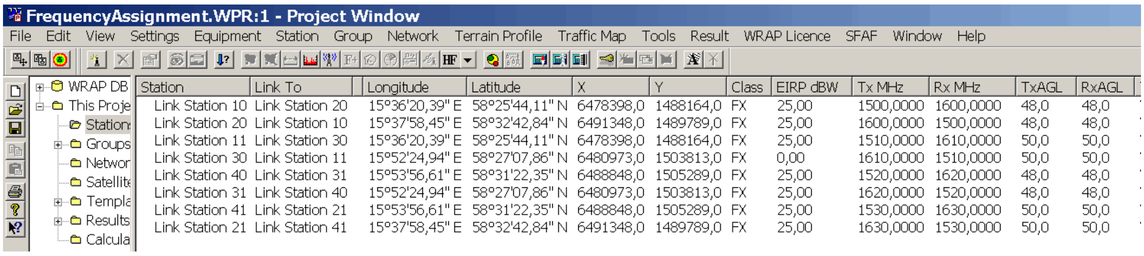


Figure 10.2: *Frequencies initially in use (assigned) to the link stations of this project.*

- Mark all Link Stations in the station list.
- Start the F+ Frequency Assignment tool.
- From the menu bar, select <**Allotment**>-<Select Allotment...>. In the table, mark the allotment named *Link raster, 10 MHz* (1500 – 1690 MHz) and click **[OK]**.

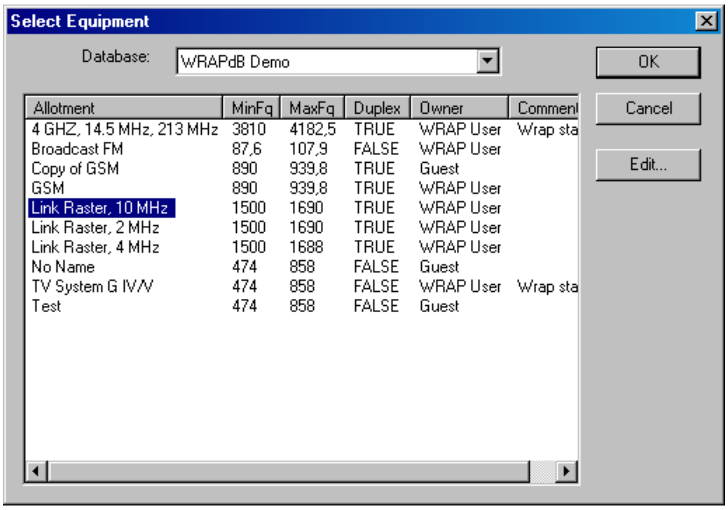


Figure 10.3: *Select appropriate allotment from the list.*

- From the menu bar, select <**Blocking**>-<Settings...>. Select the Free Space propagation model, accept the other settings in this window and click **[OK]**. Note that for radio links no default mobile should be selected.

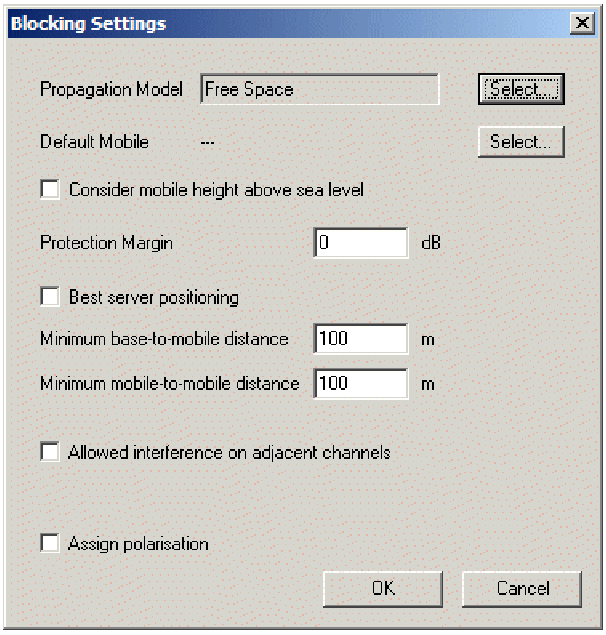


Figure 10.4: *Select a propagation model from the Blocking Settings dialogue.*

- From the menu bar, select <**Blocking**>-<Calculate>. The calculation starts.

> ***Note****: Depending on the number of stations and propagation model selected the execution time may vary considerably – compare with the fastest Free-space model! During calculation the listboxes are greyed (not available).*

- Investigate the results by marking stations and frequencies in the listboxes. Refer to instructions above and the more detailed description under *ALPHABETICAL DIALOGUE REFERENCE, Frequency Assignment*.

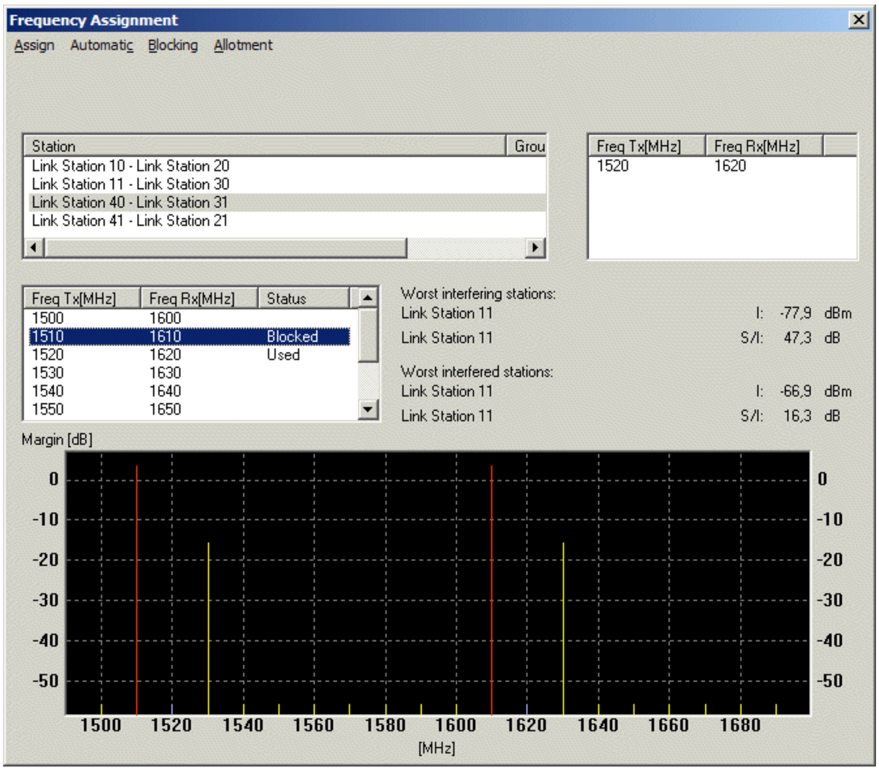


Figure 10.5: Link Station 40 marked using 1520 MHz (blue), 1510 blocked (red), all others available (yellow) for assignment to this station. Even though 1530 MHz is used by Link Station 41 it is available (not interfered).

- Now delete the frequency 1520 MHz from the assignment table for Link Station 40 (upper right table, right-click on 1520, click Delete).

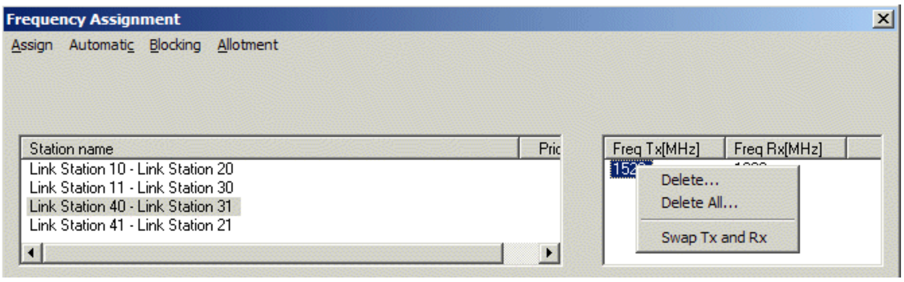


Figure 10.6: Deleting a frequency from the assignment table (right-click command).

- Then add 1500 MHz for Link Station 40 by double-clicking either on 1500 in the frequency table (middle) or on 1500 pin in the diagram. Observe the new result.

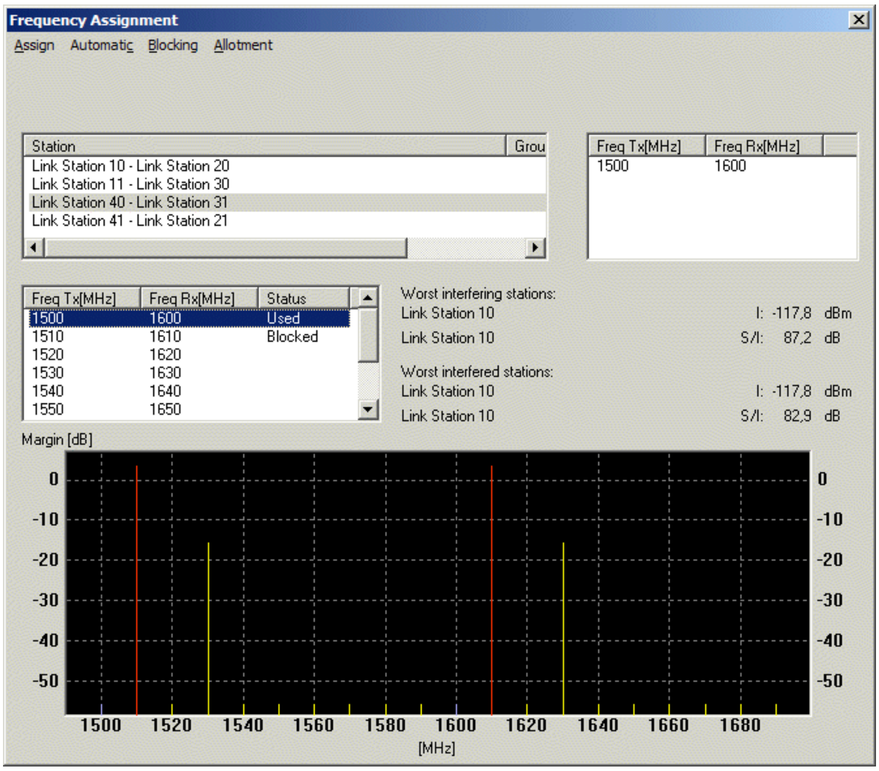


Figure 10.7: *Link Station 40, 1520 MHz replaced by 1500 MHz.*

- Proceed directly with Example 1B.

10.1.2 Example 1B: Automatic assignment, 10 MHz link allotment (continued)

- Continue from end of the Semi-manual method. Delete all assigned frequencies from the four link stations by right-clicking on one of the frequencies and selecting <Delete all…> and then respond [No] to the question whether to delete frequencies on just the selected station or on all stations.

- Then go into <**Automatic**>-<Settings...>. Accept all default settings and click **[OK].**

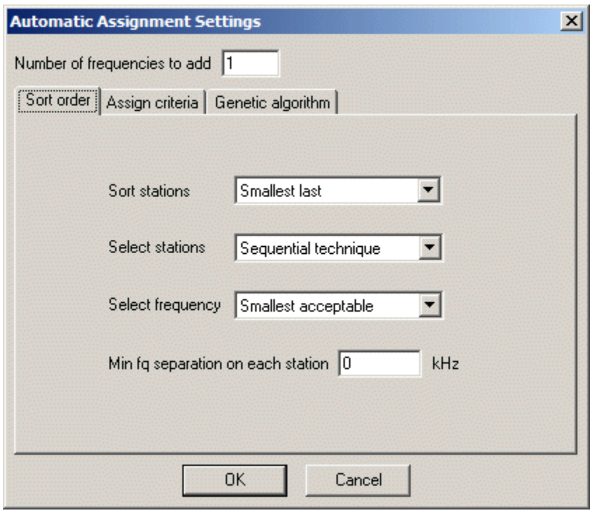


Figure 10.8: *Automatic Assignment Settings, default settings.*

- Execute an automatic assignment by clicking Automatic, Start.
- Observe the results. A more optimal assignment has now been achieved. Look at Link Station 40 again.

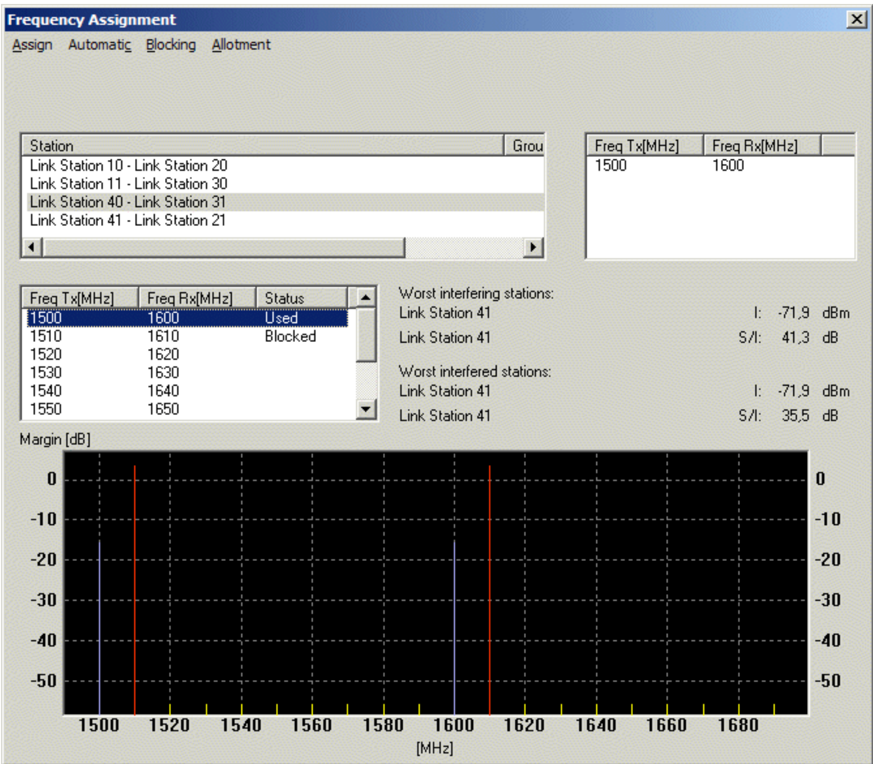


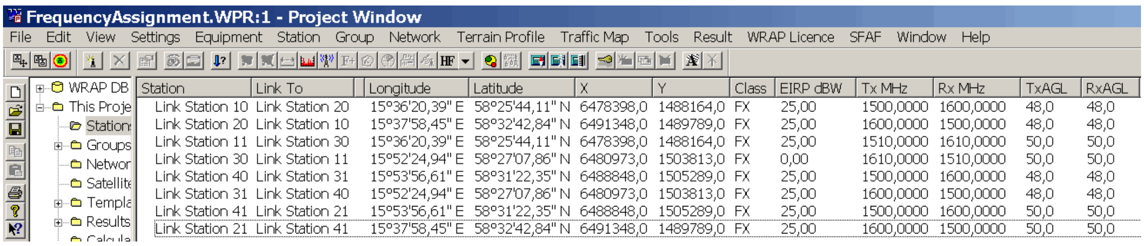
Figure 10.9: *Automatic assignment result for Link Station 40.*

> ***Note**: The Automatic and Semi-manual methods may be alternated during work as desired until satisfaction.*

- Make printouts of the assignments made. There are two options:
  - With one station marked in the upper left table: Prints the graphical diagram chart with assignment data for marked station.
  - No stations marked in the upper left table (click to the right of a marked station to un-mark): Prints assignment data for all stations but no diagrams.

- Finally, save the assignments made to the project. Select Assign, Save. If Exit is selected instead, the user is prompted with a question whether to save/not save the assignments.

- Observe the new frequency list for the Link Stations which was updated by the previous save operation. First you may need to update the list by clicking on some other folder in the folder view and then click on Stations in Project. Go back and compare it with the original list in **Figure 10.2.**



Station	Link To	Longitude	Latitude	X	Y	Class	EIRP dBW	Tx MHz	Rx MHz	TxAGL	RxAGL
Link Station 10	Link Station 20	15°36'20,39" E	58°25'44,11" N	6478398,0	1488164,0	FX	25,00	1500,0000	1600,0000	48,0	48,0
Link Station 20	Link Station 10	15°37'58,45" E	58°32'42,84" N	6491348,0	1489789,0	FX	25,00	1600,0000	1500,0000	48,0	48,0
Link Station 11	Link Station 30	15°36'20,39" E	58°25'44,11" N	6478398,0	1488164,0	FX	25,00	1510,0000	1610,0000	50,0	50,0
Link Station 30	Link Station 11	15°52'24,94" E	58°27'07,86" N	6480973,0	1503813,0	FX	0,00	1610,0000	1510,0000	50,0	50,0
Link Station 40	Link Station 31	15°53'56,61" E	58°31'22,35" N	6488848,0	1505289,0	FX	25,00	1500,0000	1600,0000	48,0	48,0
Link Station 31	Link Station 40	15°52'24,94" E	58°27'07,86" N	6480973,0	1503813,0	FX	25,00	1600,0000	1500,0000	48,0	48,0
Link Station 41	Link Station 21	15°53'56,61" E	58°31'22,35" N	6488848,0	1505289,0	FX	25,00	1500,0000	1600,0000	50,0	50,0
Link Station 21	Link Station 41	15°37'58,45" E	58°32'42,84" N	6491348,0	1489789,0	FX	25,00	1600,0000	1500,0000	50,0	50,0

***Figure 10.10:** Stations in Project frequency list updated by the Assignment tool.*

When assigning frequencies to duplex frequency links it is the station that comes first in the station list that will be assigned the lower frequency (Tx frequency). Which station comes first is decided from how the stations are marked in the project view. For instance, if you want to assign the link LinkStation21-LinkStation41 and you want Link-Station41 to get the lower frequency you must mark only LinkStation41 in the project view. Reversely, if you want LinkStation21 to get the lower frequency you must mark only LinkStation21. If you mark both LinkStation21 and LinkStation41 the station that comes first gets the lower frequency.

If you have a project with several duplex links and you know which stations should have the lower frequency you should mark only these stations and not their opposite link stations. Since it is links that you want to assign their link stations will also be assigned, but they will get the upper frequency.

10.1.3 Example 2: Assignments repeated for 2 MHz link allotment

- Select the allotment ***Link raster, 2 MHz.*** First perform a Semi-manual assignment, then remove the assigned frequencies from all four link stations. Finally perform an Automatic assignment. Observe the results.

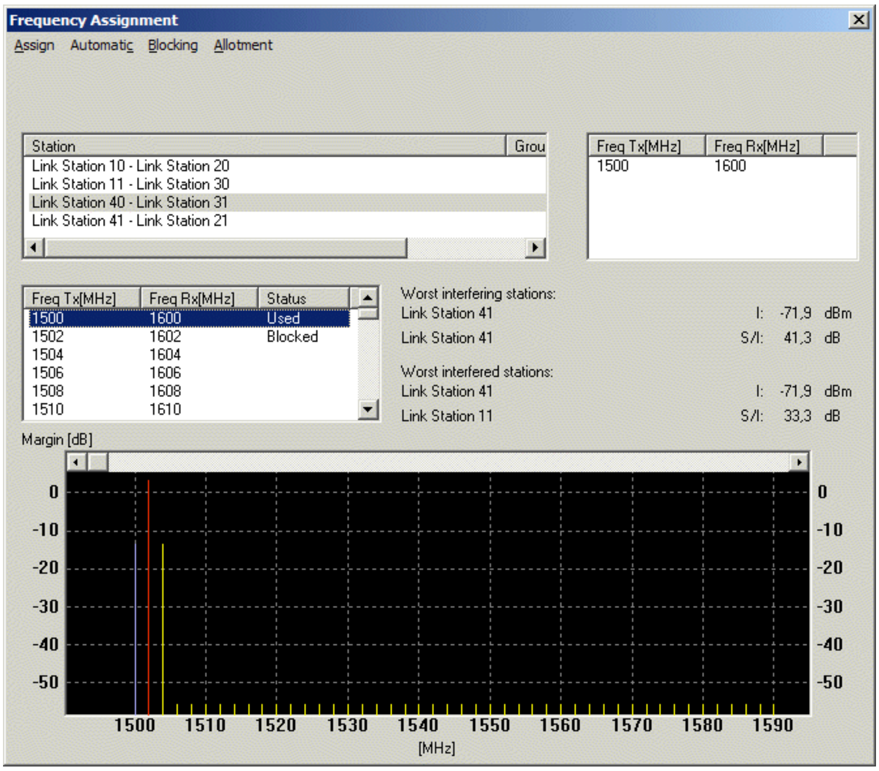


Figure 10.11: *Result of the 2 MHz Semi-manual and Automatic assignment.*

10.1.4 Example 3: Automatic assignment for a GSM cellular network

This example is used to illustrate the application of the Frequency Assignment function for an area covering service. The selected example is a small GSM network of 16 base stations that will also be used later for traffic capacity design. A suitable frequency allotment (named GSM) for this network is available in the database.

- Open the project named ***BaseStations.WPR***.

- Open the Allotment folder under the WRAP Database. Double-click on the GSM allotment in the list of allotments to see how this allotment is configured. See **Figure 10.12**. The frequency separation is 0.200 MHz and the duplex separation is 45 MHz; the base station transmitting on the high band of 935.0 - 939.8 MHz and receiving on the low band of 890.0 - 894.8 MHz. The allotment thus contains 25 channel pairs. Such an allotment can easily be created using the New Allotment function... (Create Allotment dialogue).

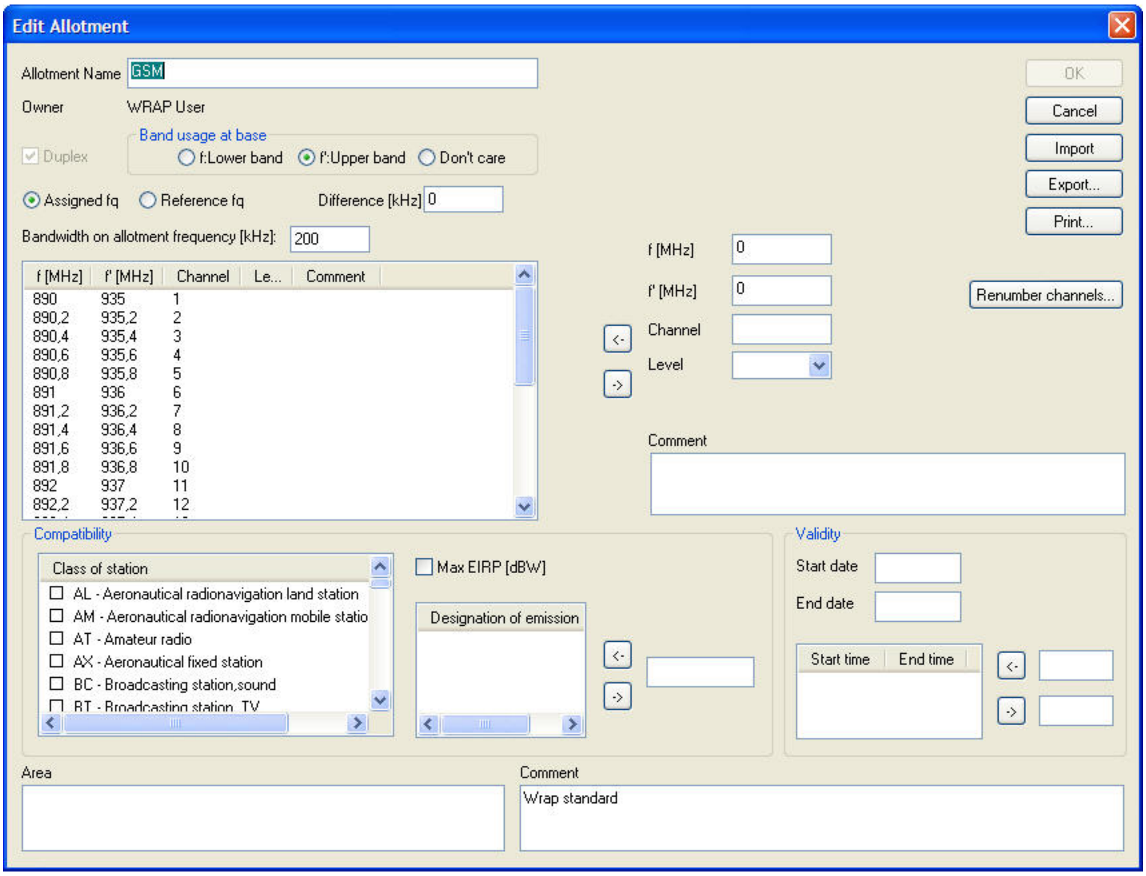


Figure 10.12: Frequency allotment to be used for the GSM example.

- Select **This Project, Stations in Project**. Note the frequencies (assignments) currently in use for the base stations. Note that all base stations transmit on 935 MHz and receive on 890 MHz. This is the initial setting for the project. This list will later be compared to the saved result at the end of Example 3.

- Mark all base stations in the station list.

- Start the  **Frequency Assignment** tool.

- From the Menu bar, select <**Allotment**>-<Select Allotment...>. In the table, mark the allotment named GSM and click **[OK]**.

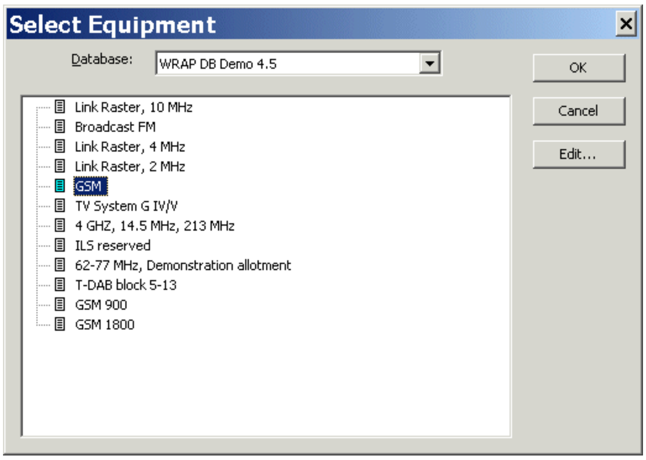


Figure 10.13: *Select appropriate allotment from the list.*

- From the menu bar, select <Blocking>-<Settings...>. Select propagation model **Detvag-90/FOI.** Using Frequency Assignment for area covering services requires the identification of what mobile station to use. Select the GSM Mobile as the Default Mobile.

There are a few other very important settings that need to be done for area covering services. Depending on the particular locations and density of base stations there may be overlapping coverage areas, where the mobiles may need to communicate without interference. Mobiles may for instance be close to a neighbouring base or close to other mobiles. In order to give a reasonable assignment of frequencies it may thus be necessary to give limits on how close to an interfering base station that a mobile may be. There will be a need for very large frequency separations, if interference protection is required very close to the interfering base, so large that the assignment may fail. Thus there is function to provide a geographical separation zone between mobiles and interfering base stations. Similarly, the separation between mobiles that are close to each other in areas where coverage from the base stations overlap can be defined.

The maximum communication range under non-interfered conditions is determined by the link budget from the base to the mobile (downlink) and from the mobile to the base (uplink). This is among other things determined by the receiver sensitivity. Under interfered conditions the maximum range is in addition dependent on the required signal-to-interference ratio (S/I). If no degradation in range is accepted under interference, the maximum interference level may be equal to the receiver sensitivity minus the required S/I value.

WRAP uses the parameter *Protection Margin* (PM) for this purpose. Setting PM to for instance -3 dB means that we will tolerate a 3 dB reduction in sensitivity, which results in a very marginal range reduction.

Continue now to set the remaining parameters for the blocking calculation in the **Menu** bar, **Blocking Settings** window:

- Use 0 dB as the protection margin, 100 m minimum base-to-mobile distance and 1 m minimum mobile-to-mobile distance. You have now selected settings according to **Figure 10.14.** Click **[OK]**.

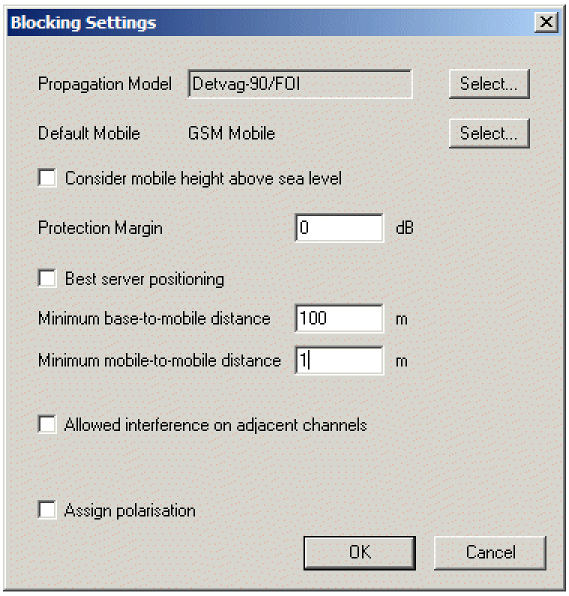


Figure 10.14: *Frequency Assignment settings for the GSM example.*

- From the menu bar, select <Blocking>-<Calculate>. The calculation starts.

> ***Note****: Depending on the number of stations and propagation model selected the execution time may vary considerably – compare with the fastest Free-space model! During calculation the list boxes are greyed (not available).*

- Investigate the results by marking stations and frequencies in the list boxes. Refer to instructions above and the more detailed description under *ALPHABETICAL DIALOGUE REFERENCE, Frequency Assignment*. See **Figure 10.15** for the result. All base stations are using the same frequencies in the initial state; hence they are all blocked.

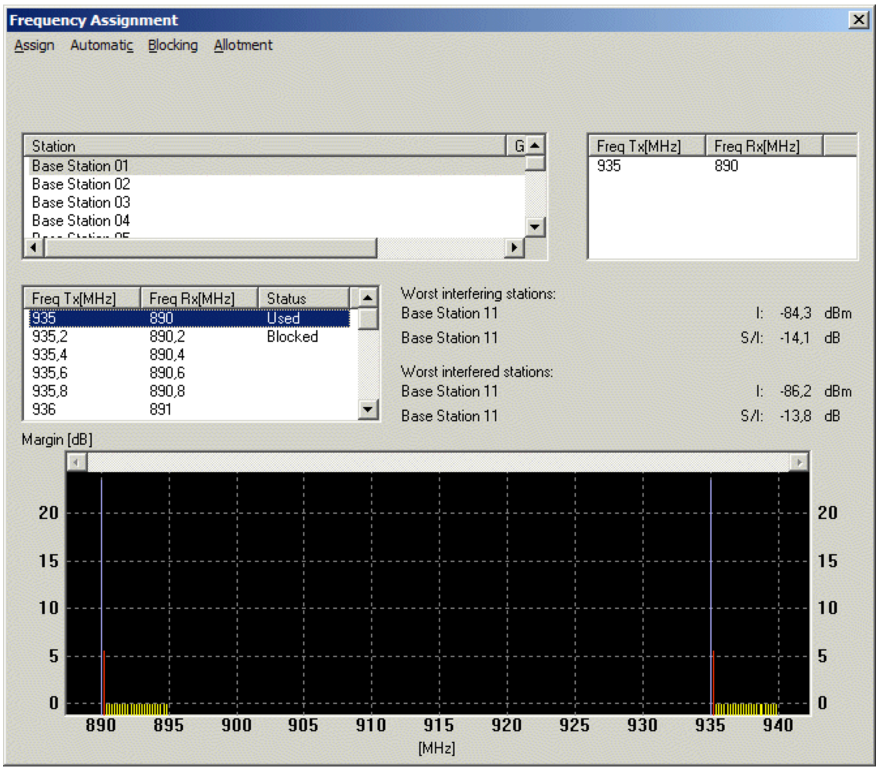


Figure 10.15: *Base Station 01 marked using 935 MHz for transmission and 890 MHz for reception.*

- Delete all the assigned frequencies by right-click on the frequency 935 MHz, select **Delete all** and respond No to the questions "Do you want to delete all frequencies for this station only?". All frequencies are deleted, and the display of the assignment margin changes appearance to show that all frequencies are available for assignment.

- You may now experiment with manual assignment as described before, either by double-clicking in the frequency table or in the margin diagram. Before continuing with the automatic assignment you should make sure that all frequencies are deleted as described above.

- From the menu bar, select <**Automatic**>-<Start> to perform the automatic assignment using the previously made settings for the automatic assignment algorithm. Wait a few moments for the calculation to finish and look at the result in the diagram and tables. You will see that all base stations were assigned frequencies

- You have now assigned one frequency to each base station. The GSM system is such that this will allow a maximum of 7 traffic channels (one channel reserved for signalling). It is possible to assign more frequencies within the selected allotment by repeating the automatic assignment, without deleting the previously assigned frequencies. Repeat the assignment three times to assign in total four frequencies to each base station. There may be a warning message that some identified base stations could not be assigned. Proceed anyway, taking note of which stations that could not be assigned.

- Select in sequence each of the base stations that could not be assigned. Look at the margin diagram to see if there are frequencies with an assignment margin very close to 0 dB. Double-click on such a selected frequency to force assignment. Having done this in this particular example may give the result shown in **Figure 10.16.**

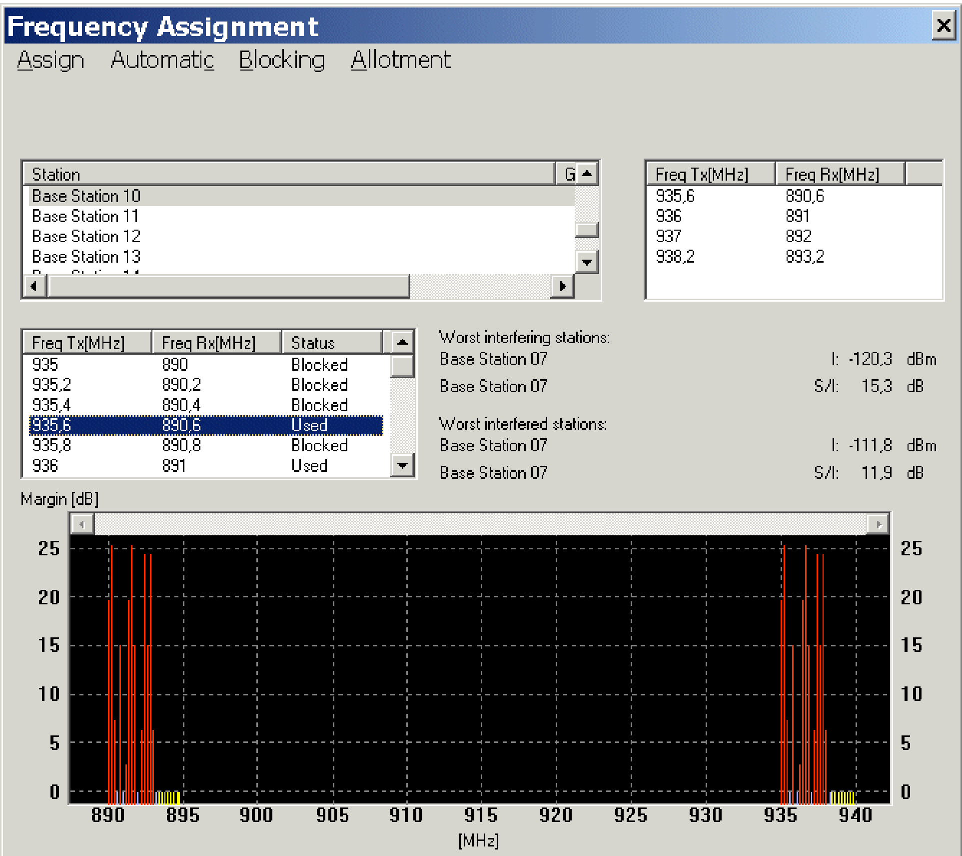


Figure 10.16: *Result of automatic frequency assignment repeated three times to assign three frequencies to each base station, complemented by manual assignment*

- `The assignment may if desired be saved to the project by selecting` **`Assign`** `and then` **`Save`** `from the Menu bar. When closing the Frequency Assignment tool the station list is updated with the new frequencies.`

The GSM network now has been assigned four frequencies to each base station, and the available frequency allotment has been fully utilised. Each base station may have a capacity of up to 31 traffic channels, with one channel reserved for signalling. Design of the appropriate number of channels will be performed later using the Traffic Capacity tool.

> ***Important note:*** *Whenever the settings in the window* **Blocking settings** *have been changed it is necessary to recalculate the blocking matrix. Otherwise the changes will not gain effect.*

Note that a mobile station linked to its current base station may be located quite near another base station, which means that there is a potential interference case of a base station transmitter interfering with the mobile receiver (and vice versa). This can happen even if the duplex separation is quite large. When performing frequency assignments for area covering services it is therefore very important that the transmitter spectrum and receiver selectivity of both the base stations and the mobile stations are defined properly. Warning messages indicating that some stations could not be assigned sometimes are due to this, which can also be identified in the margin diagram typically as all of the frequency allotments being blocked (coloured red) at a constant level.

Depending on the installation and configuration of combiners, filters etc. there may be technical limitations such that some minimum frequency separation must be maintained within a base station. It is therefore possible to define the minimum separation between frequencies assigned to the same station. This is done in the *Automatic Assignment Settings* window.

10.1.5 Example 4: Assignment of polarisation

Sometimes polarisation is used to achieve a better utilisation of the available frequency spectrum. This is particularly the case in many microwave link bands, where high-capacity links need quite a large bandwidth thus requiring close packing and a high degree of frequency-reuse.

Channelling arrangements (the general term in WRAP is *allotments*) can be pre-defined with the valid polarisations for each frequency. This is also shown in the example.

Perform the following to learn about the features in WRAP in this respect. The purpose is to assign frequencies to high-capacity links operating in parallel in the 7 GHz band.

- `Open the` **`ParallelLinks.wpe`** `project. List the stations in the project in the list view, mark all stations and` show them in the Map Viewer. Notice that all eight links are parallel, between the same two locations.

- First a suitable allotment (channelling arrangement) should be prepared as follows. Select **Equipment – New Allotment – Create** and make the following settings:
  - **Lower band - Min frequency: 6460 MHz**
  - Use tab to go to **Channel separation: 40000 kHz**
  - Tab to **Bandwidth on allotment frequency [kHz]: 40000 kHz**
  - Tab to **No of channels: 8**
  - Tab to **Duplex Spacing: 340 MHz**
  - Use the default **Channel arrangement: Polarisation independent**
  - Press **Next**
  - Enter a name for the allotment, for instance **ParallelLinks**
  - Check in **Compatibility: Fixed station**
  - Accept and close with **OK.**
  - The new allotment will appear in the list view among the previously defined allotments in the database.

- Again click on **This Project – Stations in Project** to list the stations.

- Mark all stations and select the  **Frequency Assignment** tool.

- First select **Allotment – Select Allotment** and mark the just created **ParallelLinks**. Close with **OK**.

- Select **Blocking – Settings**. Stay with the default settings but check the **Assign polarisation** box. Otherwise the calculation will only be performed for the current polarisations of the stations. Close with **OK**.

- Select **Blocking – Calculate**. The list boxes will change from grey to white when the calculation is ready.

Mark a station name in the upper left list box and notice that the margin diagram now shows the interference conditions for this link. All frequencies in the allotment are used in the original project. All stations use the same polarisation (horizontal), and this requires the use of all frequencies. Now continue to re-assign frequencies and polarisations:

- Right-click on the frequency shown in the upper right list box. Select **Delete all** and **No** on the following question, This deletes all frequencies temporarily to allow a new assignment.
- Go to **Automatic – Settings**. Check that the first tab is selected, close with **OK**.
- Select **Automatic – Start**. The assignment is soon ready.

Mark the first link in the list. Step through the list (conveniently with the up/down arrow keys) and notice that the assignment now only takes four frequency pairs. Each frequency carries two links, with orthogonal polarisation. Those links that were assigned a polarisation different from their current polarisation are identified in the upper right list box with the frequency shown in red colour.

Note that this change of polarisation has only been indicated by the frequency assignment process. Antennas need to be changed manually by the operator to really effect the changes. This is done when saving the assignment with the **Assign – Save** command. See **Figure 10.17** for the question that appears.

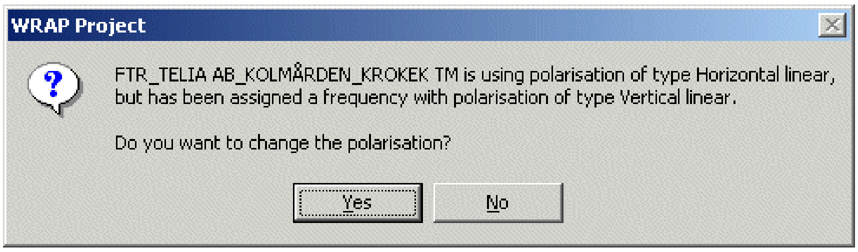


***Figure 10.17**: Information prompt to the operator that the Frequency Assignment result gave a different polarisation than the current one*

Responding **Yes** will open the **Edit Station** window for this link, and the operator may change the antennas to match the indicated new polarisation.

You may continue with the same project to see the functions when using an allotment of a type where the polarisation is linked to each frequency, such as the *Alternated, Co-channel band re-use* and *Interleaved band re-use.* The margin diagram will then show just the selected polarisation, to assist in manual assignment of the valid polarisation. The automatic assignment is performed with the additional requirement that the polarisation associated with a specific frequency must be compatible with the allotment properties.

10.1.6 Example 4: Assignment of frequencies to multiple simplex networks

In networks carrying simplex traffic all stations in the network normally receive all traffic. When the channel is busy by one station transmitting the other stations receive the traffic. They do not transmit until the channel is clear. This type of network may have an appointed base or master station, or all stations may be identical and no particular station has a specific role. Assignment in WRAP of frequencies to several of these types of networks is handled as is described in this example. There is no special project file to demonstrate the procedure, just a description how to do it.

Note that this procedure also applies for broadcast networks, where frequencies are assigned to a number of broadcast transmitters.

The WRAP project shall be prepared to **include only one station in each network**. A *Service Area* must be defined if all stations in each network should have coverage to all other stations in their network. There is no need to specify a service area for the case when it is sufficient for the mobiles to have communication just with the appointed master or base station. The service area is defined in the **Edit Station, Main** tab, and it can be defined as either a circular area around a geographical position (usually the coordinates of the station), or as a polygon defined by a number of corner points. This area should be selected to include all of the anticipated locations of the stations in the network.

The service area must be sufficiently small to provide communication range between all stations for the case of all stations to have communication with all other stations in the network. The radius of a circular service area should thus be less than half of the expected range limit.

Setting the parameters for calculation of the blocking matrix and performing an automatic assignment as has been described in the previous example will result in an assignment where the stations within each of the independent networks may communicate without interference. Appropriate selections of the minimum interfering_base-to-mobile and interfering_mobile-to-mobile distances will ensure the proper consideration to close-range interference.

10.2 THE GENETIC ALGORITHM

Frequency assignment can also be performed with a method based on a genetic algorithm. Refer to **[B05]** for a full description of this function.

The key problem in frequency assignment is to assign as few frequencies as possible to the selected transmitters without causing interference between them. The purpose of using a genetic algorithm in frequency assignment is to perform assignment considering several potentially conflicting requirements by weighting between them and to provide an inherent randomness in the assignment process.

Genetic algorithms attempt to simulate nature in the following manner. The first step is to represent a solution to the problem by a string of *genes* (in this case frequencies) that can take on some value from a specified finite range or alphabet. This string of genes, which represents a solution, is known as a *chromosome*. Then an initial population of legal chromosomes is constructed at random. For each generation, the fitness of each chromosome in the population is measured (a high fitness value would indicate a better solution than a low fitness value or vice versa). The fitter chromosomes are then selected to produce offspring for the next generation, which inherit the best characteristics of both the parents. After many generations of selection for the fitter chromosomes, the result is hopefully a population that is substantially fitter than the original.

Each chromosome represents a possible solution to the problem and is composed of a string of genes. An initial population is created to serve as the starting point for the genetic algorithm. This initial population is created randomly. The population size in this implementation is 50.

Fitness evaluation of each chromosome is performed using a fitness function against which each chromosome is tested for suitability for the environment under consideration. As the algorithm proceeds the individual fitness of the "best" chromosome normally increases as well as the total fitness of the population as a whole.

Once a pair of chromosomes has been selected, crossover can take place to produce offspring. A so-called one-point crossover is used in this implementation.

If the crossover operator is used to produce offspring, one potential problem that may arise is that if all the chromosomes in the initial population have the same value at a particular position then all future offspring will have this same value at this position. For example, if all the chromosomes have a 0 in position two then all future offspring will have a 0 at position two. To combat this undesirable situation a *mutation* operator is used. This completes one cycle of the simple genetic algorithm. The fitness of each chromosome in the new population is evaluated and the whole procedure repeated until finished by running through the user-defined number of generations.

Figure 10.18 shows the settings for the genetic algorithm. The following potentially conflicting criteria can be applied:

- Minimum bandwidth: Attempts to minimise the frequency separation between the highest and the lowest assigned frequency.

- Few frequencies: Attempts to minimise the total number of frequencies for the assignment.

- Interference: Attempts to minimise the interference between frequencies in the assignment.

- Prioritised interference: Attempts to assign frequencies with low interference to prioritised stations/nets

- Collocation interference: Attempts to assign frequencies accounting for all the selectable forms of interference that are considered in the collocation interference calculations. Refer to **Figure 10.18** for the settings.

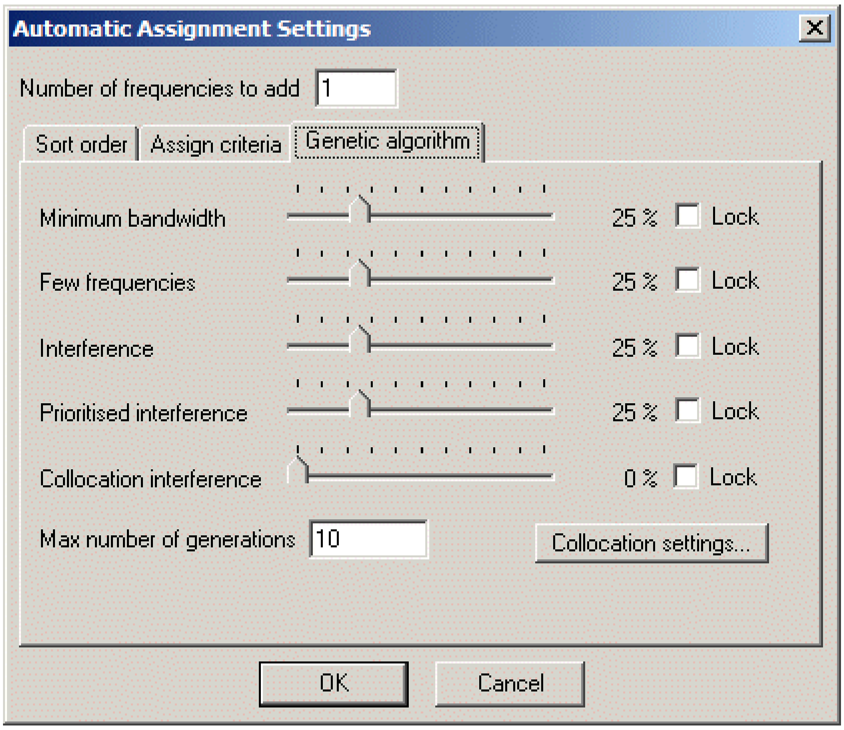


Figure 10.18: *Settings for the genetic algorithm*

The finish criterion is given by *Max number of generations* .

10.3 ASSIGNMENT TO NETWORKS

Stations can be defined to belong to networks. In this case the assumption is that stations within a network do not interfere with each other, since only one station in a network transmits at a time. Networks may have a *Main* frequency and a *Reserve* frequency, each of which can be assigned independently. All stations in the network use either the Main frequency or the Reserve frequency. There are a number of specific considerations that are important in the case of frequency assignment to networks:

- Stations within a network do not interfere with each other
- The interference is evaluated in the receivers of the stations in all networks in the project, at their defined geographical locations, if there are no free stations (i. e. stations not belonging to any network) in the project
- Interference is evaluated for mobiles as described previously if at least one station in a network has a defined service area. Mobiles are placed towards all the other stations in the project.
- Interference is evaluated for mobiles as described previously if there are free stations (i. e. stations not belonging to any network) in the project
- All stations within a network are assigned the same frequency

- A selection is available in the *Settings* window to define if the assignment is intended for the *Main* frequency (*Reserve* frequency if *Main* is not selected).

Both the graph-colouring and the genetic algorithms are available for Network assignment. A specific genetic method is used for the Network assignment, having the following properties:

- A setting for the minimum frequency separation between the *Main* and *Reserve* frequencies. This is not considered if no main frequency and/or reserve frequency exists.

- The assignment is performed based on minimum interference

- Assignment is only performed to the networks when selecting the *Genetic: Net assignment* function, not to free stations in the project (if there are any)

- Assignment is only performed to the free stations when selecting the station orientated *Genetic algorithm*, not to networks in the project (if there are any)

The margin diagram can be selected to show either a station-orientated graph, showing the interference situation for each station, or a network-orientated graph, which shows the situation for the worst interfered/interfering station within each network. Manual frequency assignment to networks can be performed just as for free stations, using the coloured information and the values in the margin diagram as guidance to suitable frequencies.

The sorting of stations in the graph-colouring algorithm is performed with a network-priority in projects containing both free stations and stations belonging to networks. This is done by sorting the network-stations first in the lists as defined previously.

10.4 MULTIPLE FREQUENCY ASSIGNMENTS

The number of frequencies to assign to a station can be defined (for both types of assignment algorithms). Normally this number is set to “1” (single frequency). When setting “2” two frequencies are assigned to each station, and this may for instance represent the normal frequency and one reserve frequency.

This feature can also be applied to assign frequencies to frequency-hopping stations with a table-defined frequency utilisation. It should be noted that only the genetic method will give a random assignment.

Multiple assignments can be performed for both the Main frequency and Reserve frequency, both for fixed frequency networks and frequency hopping networks (with table-defined frequency definition). This allows the generation of a main frequency table and a reserve frequency table for frequency hopping networks.

10.4.1 Example: Assignment of frequency tables to frequency hopping networks

This example demonstrates the following functions:

- Assignment of frequencies to networks
- Consideration to interference in a site where several different networks have one station each, thus giving rise to significant interference
- Application of a genetic algorithm to give a random assignment
- Assignment of frequency tables to frequency hopping networks.

The example should only be attempted on a fast computer, as the calculations are extensive and take a few minutes even on a very fast computer.

First create a new allotment with the following properties:

- Start frequency 30 MHz, end frequency 87 MHz
- Frequency separation 500 kHz (total of 115 frequencies)
- Bandwidth 25 kHz
- Simplex, polarisation independent.

Then perform the following:

- Open the project **FHNetworks.wpe.** List all stations in the list view and display the stations in the Map Viewer. You may also list the networks by selecting **This Project – Networks in Project** in the folder view. Again list all stations in the list view and note that three of the stations belong to a site. The distance between the stations in the site is about 10 m.
- Mark all stations and start the F+ **Frequency Assignment** tool.
- Make the following selections:
  - **Allotment – Select Allotment.** Choose the allotment with the mentioned properties in the introduction.
  - **Blocking – Settings – Propagation model – Longley Rice.** Uncheck **Assign polarisation.**

  Note that no mobile should be selected, as the communications links are assumed to be between the stations in the networks, at their fixed locations. A mobile may however also be selected, and will then in addition be placed at test points as described in the introduction to this chapter.

- Select **Blocking – Calculate**.

There is a possibility to show the margin diagram for the complete networks or for each individual station. This choice is made my checking or unchecking the **Show nets** box. The margin diagram shows the worst interference condition taken over all individual stations when the **Show nets** box is checked. This shows the blocked, used and assignable frequencies for the network.

- Check and uncheck the **Show nets** box to see the difference in the display while marking the net name or station name, as applicable, in the upper left list box. Then right-click on a frequency in the upper left list box, select **Delete all** and answer **No** on the subsequent question whether to delete all frequencies for this station only.

- Then go to **Automatic – Settings – Net assignment** and enter **20** in **Number of frequencies to add**. Close with **OK**.

- Select **Automatic – Start**. The calculation will take some time, very much dependent on the speed of the computer.

- When the calculation is ready you can mark one of the nets and see which frequencies that were assigned. An example of a result is shown in **Figure 10.19.**

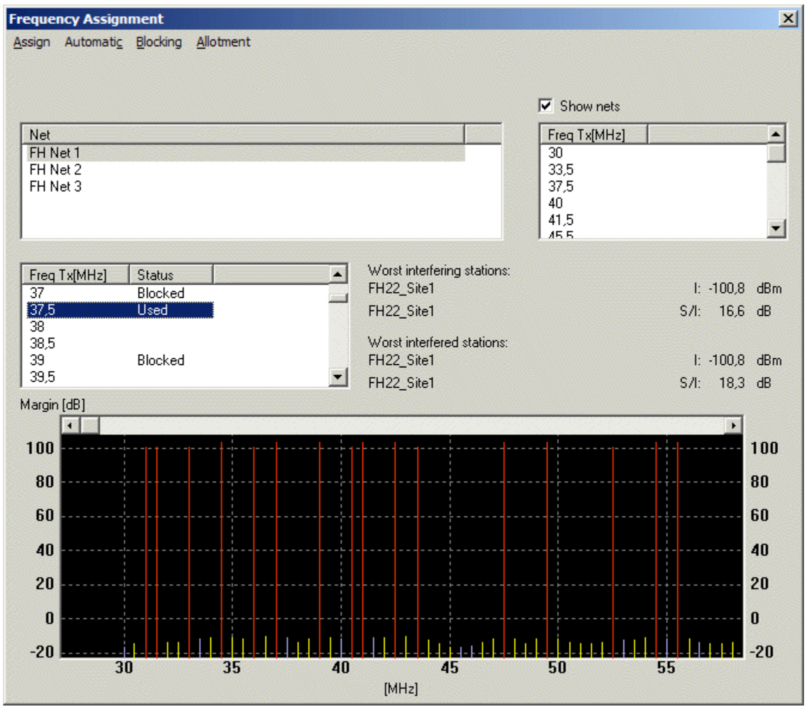


Figure 10.19*: Example of result from automatic assignment of 20 frequencies each to three frequency hopping networks.*