RF3D WifiPlanner

manual

for RF3D WifiPlanner and RF3D WifiPlanner Lite

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1 Introduction

Thank you very much for choosing RF3D WifiPlanner! RF3D WifiPlanner is an advanced program for planning wireless networks in conformance with the IEEE 802.11a/b/g/h standards. RF3D WifiPlanner helps you design more efficient wireless networks and ensure that they deliver optimum service even under heavy loads. Such planning usually saves costs too, not least by eliminating unnecessary access points. This also means less radiation, which is another benefit that should not be underestimated.

The number of wireless networks in professional use is constantly growing. For companies that want full WiFi coverage using multiple access points, there is no substitute for professional and efficient planning. Until now, however, it has been difficult to optimize the time and money spent on planning robust, high-availability wireless networks, especially in multi-story buildings. RF3D WifiPlanner software by Psiber Data meets this need, providing economical, application-specific planning of both simple and complex wireless networks.

RF3D WifiPlanner provides true three-dimensional simulation of radio signal distribution in the building, and is thus the first tool to visualize co-channel and next-channel interference from access points on other floors. Furthermore, the number of access points required can be easily optimized through on-screen interactive planning. And this planning software pays for itself with the first unnecessary access point you save. Wireless network planners usually provide for too many access points, and more access points do not generally improve the network quality. Instead, they cause channel overlap, which is often unavoidable, especially in 2.4 GHz networks. As a result, complex wireless networks are usually relatively error-free at low data rates, but as data rates increase, errors become more frequent. But RF3D WifiPlanner lets you optimize your network specifically for the use you anticipate.

RF3D WifiPlanner uses theoretical principles to calculate signal distribution. The network as installed and its actual coverage may deviate from the results of such calculations. Because the calculations are based on theoretical values, Psiber Data assumes no liability for the accuracy of the results.

1.1 PC 1.1PC Hardware Requirements

• Processor: Intel Pentium, 1.5 GHz or faster

• Display: 1024×768 or greater
• RAM: 750 MB for networks with less than 30 access points.
  For larger network plans, 1 GB or more.

1.2 Installation and Activation

Before installing the software, please open Add or Remove Programs under Start / Control Panel, and verify that the Microsoft .NET Framework 2.0 (or higher) has been installed on your computer. If it is not already installed, please download the Microsoft .NET Framework from www.microsoft.com and install it before you continue.

Furthermore, make sure that you have Administrator privileges on your PC and a working connection to the Internet.

Insert the installation CD into your drive. If the installer does not start automatically, double-click the installation file to start it.

After starting the installer, you will see the welcome message.

Click Next

Now choose the installation folder for the program. We recommend using the default directory path. Please do not change the name of the application folder, "RF3DWifi-Planner". Click Next and wait for the installation to be completed.

After you click Finish, RF3D starts and displays a license activation dialog:
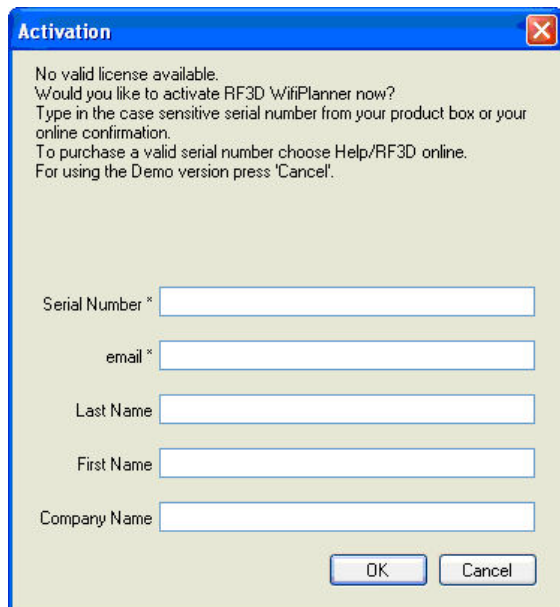
If you would like to evaluate the software in demo mode, simply click Cancel. Otherwise, enter the serial number from your CD box or online purchase confirmation, your name, the name of your company, and your e-mail address. Click OK. The following dialog appears:

For the next step, please make sure that the computer is connected to the Internet. After you have successfully activated the software, you will see the following dialog:

Click Close to conclude the installation and activation, and start working with your RF3D WifiPlanner.

1.3 Product Updates

New versions of RF3D WifiPlanner are released from time to time. To search for updates, please visit www.rf3d.com in the Internet. The RF3D website has a download area where you can download the latest program version.

The same website allows you to upgrade from RF3D WifiPlanner Lite to the next higher version. Or you can order an upgrade by e-mail to sales@rf3d.com.

Fundamentals of Wireless Network Planning

To plan an efficient wireless network, it helps to understand a little radio communication theory. In this document we can only provide a brief summary with regard to wireless networks. For more detailed information, please consult the specialist literature.

2.1 Standardization in Wireless Networking

In designing standards for wireless networks as they are used in the industry today, the IEEE built on the Ethernet standard, IEEE 802.3. Like Ethernet, an IEEE WLAN functions as a shared medium with a decentralized access control mechanism. Every station competes for access with all other stations, and is responsible for regulating its own use of the medium. In this situation, the CSMA/CD access protocol (Carrier Sense Multiple Access with Collision Detection) ensures that every station gets an opportunity to transmit data over the medium. Because it uses the same media access technique, 802.11 WLAN is often called "wireless Ethernet".

The IEEE 802.11 standard defines several different Ethernet-based wireless networks. The most common of these are 802.11a, b, g and h. In general, two different radio techniques are used in two different frequency bands. The 2.4 GHz ISM band is most often used. This band is reserved worldwide for license-free industrial, scientific and medical applications. The frequency band used can vary from one country to another, however. For example, eleven channels can be used in the 2.4 GHz band in the United states, while up to 14 channels are available in other parts of the world. The other frequency band used for wireless Ethernet is around 5 GHz. In addition to the frequency bands, the IEEE standards also specify transmitter power, data rates, packet structure, management packets, and much more.

2.1.1 The IEEE 802.11b Specification

The wireless Ethernet standard IEEE 802.11b, adopted in late 1999, is the first such standard to be widely supported for both industrial and home use. Networking components that support this standard communicate in the 2.4 GHz band. The specified data transfer rates are 1, 2, 5.5 and 11 Mbit/s.

2.1.2 The IEEE 802.11g Specification

The IEEE 802.11g wireless Ethernet specification is an advanced extension of the widely accepted 802.11b standard, and was adopted in mid-2003. Like its predecessor, 802.11g also uses the 2.4 GHz frequency band. The data transfer rates were substantially increased, however, so that the 802.11g standard permits throughput of 1, 2, 6, 9, 12, 18, 24, 36 and 54 Mbit/s. Networking components that conform to the g specification are also compatible with the earlier b standard. For this reason, such components are often designated as "802.11 b/g compatible".

2.1.3 The IEEE 802.11a Specification

The 802.11a extension to the IEEE wireless Ethernet standard was adopted in late 1999. Unlike b and g networks, 802.11a uses the 5 GHz band. The advantage here is that channel overlap is less frequent. The drawback, however, is that the 5 GHz band is subject to various regulations and restrictions in some countries. Like the g standard, 802.11a specifies throughput rates of 1, 2, 6, 9, 12, 18, 24, 36 and 54 Mbit/s.

### 2.1.4 The IEEE 802.11h Specification

Although IEEE 802.11b equipment became widespread all over the world around the turn of the millennium, the market for IEEE 802.11a products developed relatively slowly. In some countries, the regulatory agencies had not yet approved public use of the frequency band. The IEEE 802.11h extension was a substantial prerequisite to the use of products in conformance with the a standard in Europe. One major innovation of the h specification is that components monitor the desired channel for other applications, such as radar, which could otherwise be impaired by wireless network operation. In case of such interference, the WLAN equipment either reduces its transmitter power or shuts down. The operator can then select a different channel.

2.2 Frequencies and Channels

All the wireless standards described here work with fixed channel settings, not with "frequency hopping" as used by other technologies such as Bluetooth. The 2.4 GHz ISM band is divided into 14 channels. Channels and frequencies are subject to different local regulations in each country, however, which must be taken into account during planning. For example, in the US, only channels 1 to 11 are used, while in Europe channels 1 to 13 are available. It is generally up to the operator to ensure that local regulations are observed.

Channel	Center frequency [GHz]	Area
1	2.412	USA FCC, Europa ETSI, Japan
2	2.417	USA FCC, Europa ETSI, Japan
3	2.422	USA FCC, Europa ETSI, Japan
4	2.427	USA FCC, Europa ETSI, Japan
5	2.432	USA FCC, Europa ETSI, Japan
6	2.437	USA FCC, Europa ETSI, Japan
7	2.442	USA FCC, Europa ETSI, Japan
8	2.447	USA FCC, Europa ETSI, Japan
9	2.452	USA FCC, Europa ETSI, Japan
10	2.457	USA FCC, Europa ETSI, Japan
11	2.462	USA FCC, Europa ETSI, Japan
12	2.467	Europa ETSI, Japan
13	2.472	Europa ETSI, Japan
14	2.484	Japan

However, the channels in the ISM band overlap. For example, with reference to the actual radio output of an access point, we find that an access point transmitting on channel three also emits a signal on the neighboring channels 1, 2, 4, and 5. This means that other WLAN components communicating on any of those four channels will receive interference. This happens whenever the components transmit data. Data transmission generally occurs even when no user data is transported over the network — in other words, when the network is idle — because management information, beacons, keep-alive packets and the like still have to be transported at regular intervals. This phenomenon is called near-channel interference.
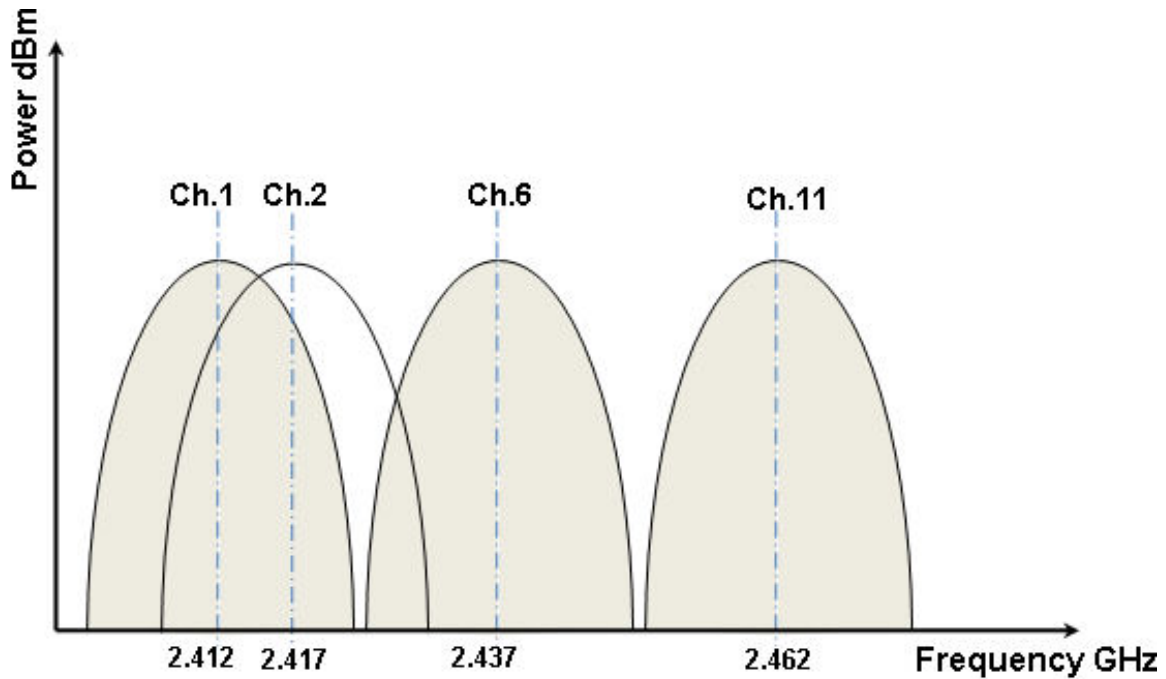
Interference arises whenever data is transmitted, and therefore networks that carry little or no data generate less interference. This also means that, although a network with lower data traffic still functions in spite of channel overlap, problems can be expected as traffic increases. In planning, of course, attention must be given to avoiding channel overlaps. This is done by planning overall WLAN network as a cellular structure in which adjacent cells use channels that are far apart in the frequency spectrum. Among the eleven channels available in the US, no more than three can be used with no overlapping: channels 1, 6, and 11.

It is also helpful to know that the maximum permissible transmitter power in this ISM band for indoor use is 20 dBm, or 100 mW.
The 5 GHz frequency band offers a greater number of non-overlapping channels, but is often subject to national regulations. Different countries permit different maximum indoor and outdoor transmitter power levels, for example.

2.3 Cellular Structure of a Wireless Network

The size of a wireless cell — that is, the coverage area of an access point — is limited by the transmitter power. To cover larger areas, a structure of several adjacent cells is recommended. Because the adjacent cells overlap spatially, they must use distinct, non-overlapping channels.

802.11 a/h

802.11 b/g
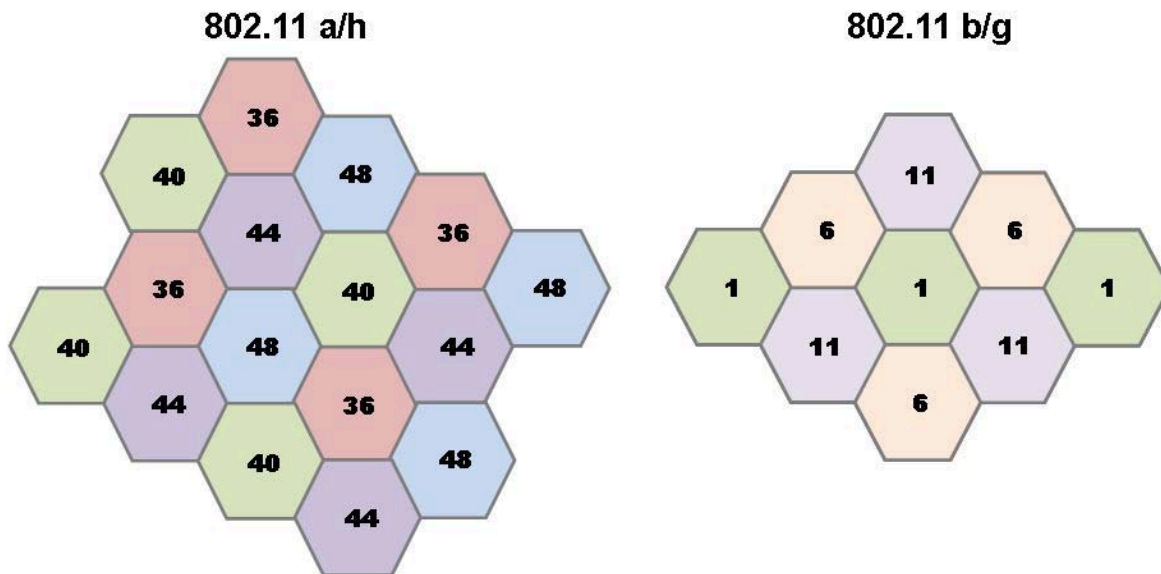
Note that, in this cellular structure, channel overlap must be avoided not only within each floor of a building, but also between adjacent floors. In other words, access points above and below one another should not use the same channels.

Another important consideration is the security of a company-wide wireless network. Usually the operator wants to avoid WLAN transmission beyond the boundaries of the company's premises in order to prevent unauthorized access from outside. Furthermore, in designing the network's cellular structure, you should also consider what applications are to be transported over the network. If an application such as telephony is to be provided over the WLAN, then each cell — that is, each access point — is usually supposed to support a specific number of simultaneous calls. This is usually not feasible in cells of the greatest possible size, so the network should be designed with smaller cells. Smaller cells can be achieved by reducing the transmitter power of specific access points. In this case, of course, more access points are required to cover a given area.

Another consideration in planning wireless cells is that the data rate depends in part on the signal power received at any given point. For applications with low data traffic, such as warehouse or logistics applications, it can be efficient to use the outer fringes of a cell in spite of weaker signal power.

2.4 Antennas

Antenna technology would take up a full chapter in a survey of WLAN fundamentals. For planning purposes, you need to know that cell shapes can be optimized by using appropriate antennas. In office floors, for example, signal radiation in a horizontal plane is very important, while vertical radiation is often undesirable, since it causes interference in the floors above and below. A highly directional antenna, such as a panel antenna, may be used to cover a long corridor. Yagi antennas have an even narrower beam and are used for point-to-point communications, such as radio links between two buildings.

2.4.1 Omnidirectional Antennas Omnidirectional antennas are generally used to increase the communication range within offices or homes. The antennas commonly supplied with access points are omnidirectional. Omnidirectional antennas have a beam angle of 360° in the horizontal plane. Vertically, their radiation pattern is compressed, and may cover an angle of 80°. These antennas can have a gain of 2 to 5 dB, and may be used to increase an access point's horizontal range.

Please see appendix A: The Antenna Library

2.4.2 Patch Antennas Patch antennas typically offer gain of 4 to 6 dB, with horizontal and vertical beam angles of 80° to 65°. A patch antenna can increase the communication range by up to 100%.

2.4.3 Yagi Antennas Yagi antennas are extremely directional antennas, and are used to set up point-to-point radio links, bridging distances of up to 300 m at 54 Mbit/s, 1 km at 11 Mbit/s, or 2 km at 2 Mbit/s for example using 2.4 GHz WLAN. In this way separate buildings can be interconnected using WLAN equipment.

Please see appendix A: The Antenna Library

2.5 Attenuation

Once the signal leaves the access point's antenna, it is subject to attenuation, or loss: that is, it becomes weaker. In the ideal case, the signal attenuation with increasing distance from the antenna is called free-space loss. The theoretical rate of free space loss is different for the different frequency bands, 2.4 GHz and 5 GHz. A 5 GHz signal is subject to greater loss than a 2.4 GHz signal. Indoors, the actual attenuation depends on the given building. The signal loss through wooden walls is clearly different from the loss through stone or reinforced concrete. It is therefore important to determine the building materials involved and their specific properties.
Please see appendix B: The Wall and Floor Library

2.6 Theoretical Throughput Rates

Signal strength is one of the factors that determine the theoretical throughput of a wireless LAN. Wireless LAN components lower their data rate automatically when the received signal power is no longer sufficient for a higher throughput. Furthermore, the received signal must also be greater than the noise due to interference, typically by 10 dB. Thus the signal quality is characterized in terms of the signal-to-noise ratio (SNR).

Data Rate for 802.11 g							
SNR dB) RSSI (dBm)	4	5	6	7	8	9	10	11
-94	1	1	1	1	1	1	1	1
-91	1	1	2	2	2	2	2	2
-87	1	1	2	2	5,5	5,5	5,5	5,5
-86	1	1	2	2	6	9	9	18
-84	1	1	2	2	6	9	9	18
-82	1	1	2	2	6	9	11	24
-80	1	1	2	2	6	9	11	36
-75	1	1	2	2	6	9	11	48
-71	1	1	2	2	6	9	11	54

2.7 Redundancy

To protect the supported applications against failures, a certain redundancy must be designed into a wireless network. This means that, if a given access point fails, the stations it served can join neighboring radio cells. However, since access points too close together generally cause interference, redundancy planning always involves a compromise between reliability and throughput.

The RF3D User Interface

RF3D WifiPlanner's user interface has been designed to display even complex WLAN plans understandably. RF3D WifiPlanner calculates three-dimensional radio characteristics in real time, and displays them in horizontal cross-sections corresponding to the floors of a building. A navigation column at the left presents simplified thumbnails of all the floor plans. The selected floor is displayed in detail in the main window, where you can edit it interactively. The tabs at the bottom of the window allow you to select the Simulation, Access Points and Advanced options.
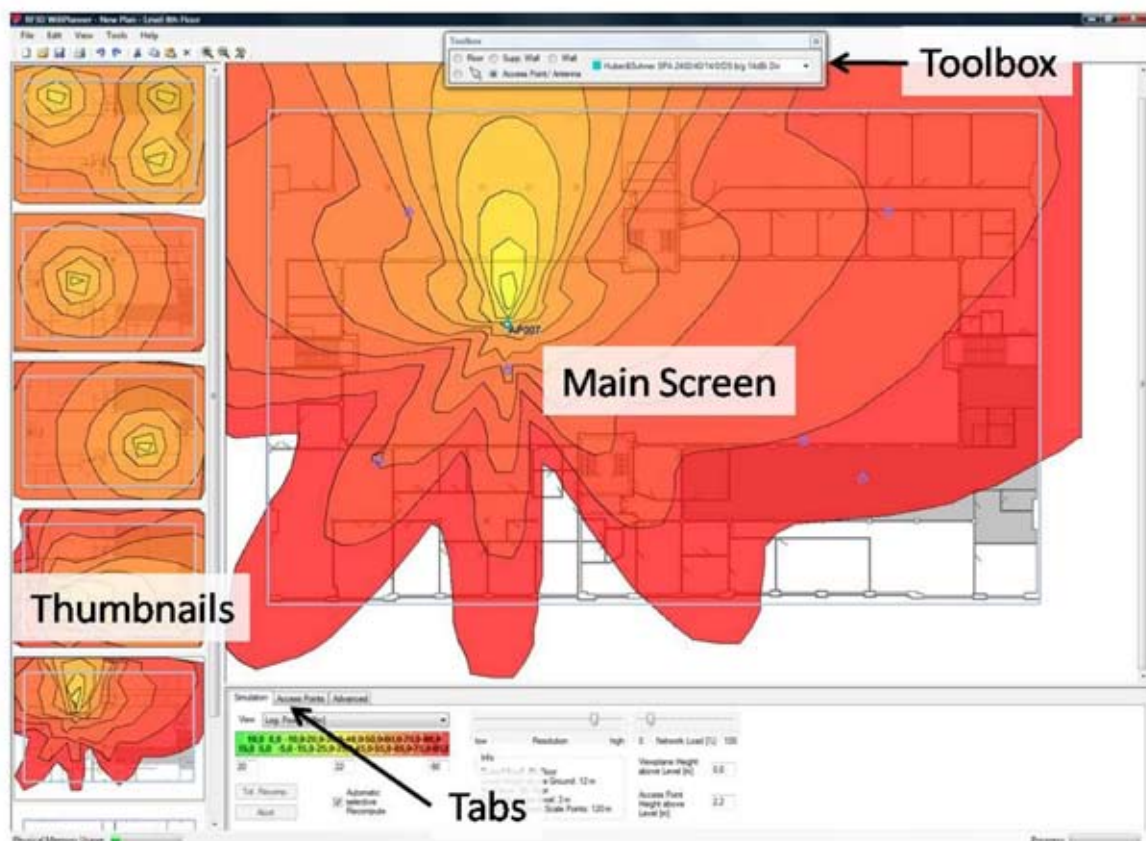
3.1 Importing Building Plans

For an exact simulation of floors one above another, the building plans must be aligned. For this purpose the RF3D WifiPlanner includes an Import Wizard to assist you in importing individual floor plans in alignment with one another. Floor plans can be imported in the common image formats JPG, BMP and PNG. In selecting floor plans, you should choose image files of moderate size and resolution, since high-definition floor plans consume memory unnecessarily. We recommend that you use images of less than 1000 × 1000 pixels. If your plans are cur-

rently in DXF format (as produced by Auto-CAD for example), you can convert them either using the graphics program they were created with, or using commonly available utilities. Other ways of obtaining the necessary plans include scanning paper drawings or photographing the emergency exit plans posted on each floor of most buildings. It doesn't matter if the individual floor plans have different resolutions or orientations: the Import Wizard solves such problems easily.

To start the Wizard, select the menu command **File/New.**

Click **Next** to import an image file of the first floor plan. Browse to the desired image file in the file selection dialog.

To ensure that all the floor plans for the whole building are aligned one above another, you must choose two corresponding reference points in each plan. RF3D WifiPlanner automatically scales and rotates the individual plans to align the selected points exactly in vertical lines. You only need to take care to select the two points so that they can be identified exactly on every floor plan. It is a good idea to select the upper left and right corners of the building as reference points, for example. Furthermore, you must enter the exact distance between the two reference points. Specify the distance in the measurement unit selected in the program options, feet or meters.
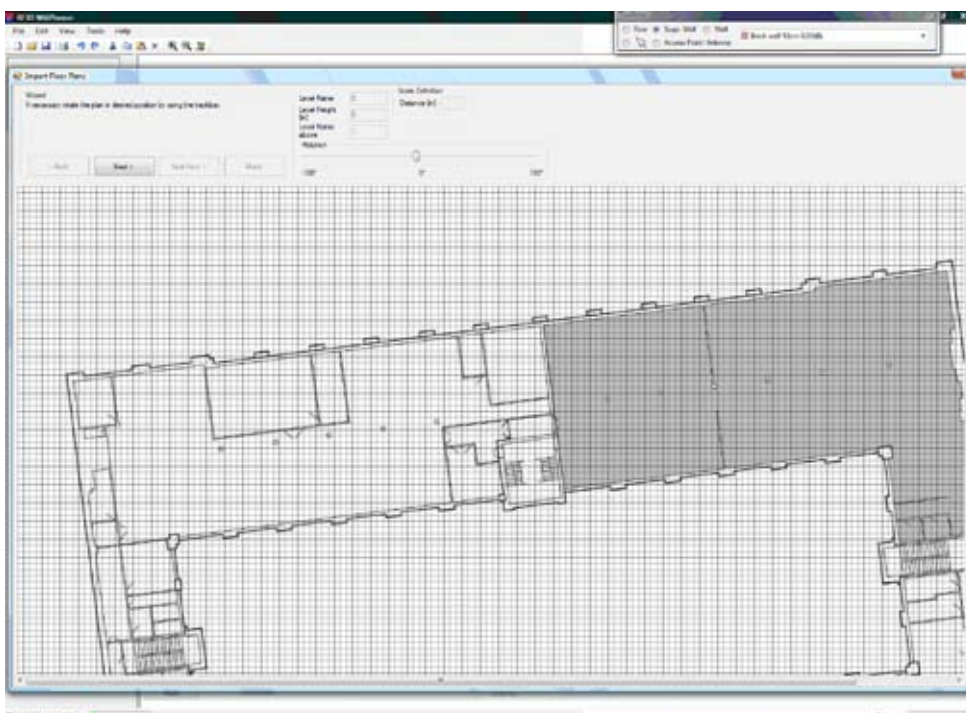
After you have selected the image file for the first floor plan, you can align it with the grid so that the walls are exactly horizontal and vertical. This will make it much simpler to draw in the walls later. To align the plan, rotate it using the slider, then use the left and right arrow keys for finer adjustments.
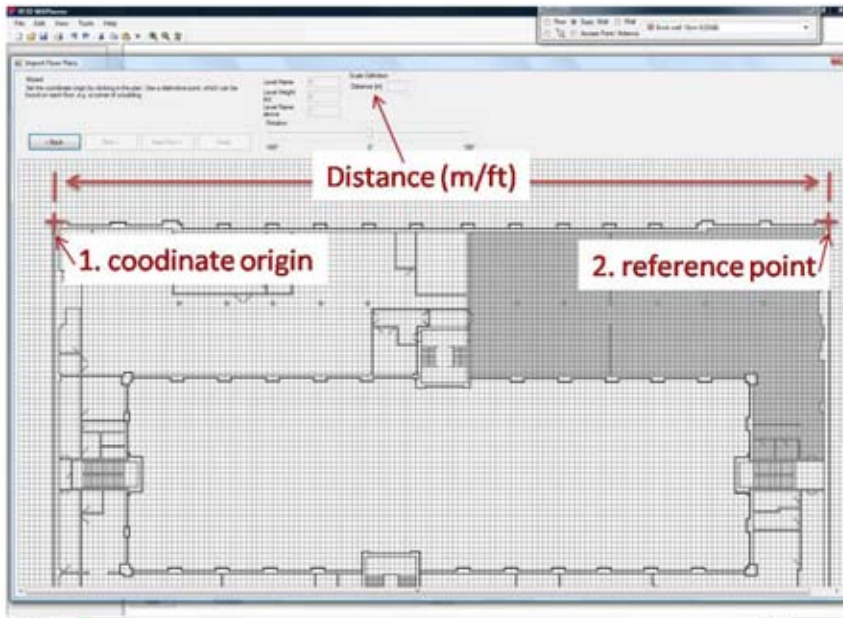
Then set the "coordinate origin," such as the upper left corner of the building, and a second "reference point," such as the upper right corner of the building. Remember that the same two points must be identifiable on the plan of every floor. Now enter information about the plan, including the following items:

Level Name: Specify a name for the current floor, such as "Ground Level" or "Fifth Floor".

Level Height: Enter the floor's elevation above ground level. This value can be negative if your planning includes underground levels.

Level Name above: Enter the name of the floor above the current floor. When you later import the next higher floor plan, be sure to give it the name you indicate here. Mismatched next-level names should only occur in special cases, such as split-level building plans.

Distance: Specify the distance between the two reference points on this floor. You should enter this distance as exactly as possible, since coverage calculations may otherwise be inexact.

Now click **Next Floor** to import the next plan. This time you do not need to align the image. Simply click on the same two reference points as in the first plan, in the same order. Repeat this procedure until you have imported all the floor plans. Click **Finish** to close the Wizard.

3.2 The Toolbox

The Toolbox provides all the tools you need to design a wireless LAN. When you select **Floor, Supp. Wall, or Wall,** the drop-down list to the right in the Toolbox contains a list of the possible material types for the corresponding building element. To draw in building elements on the plan, select a material type in the list. The material types are stored in the program as libraries, which can be easily expanded. For details, see Chapter 5, "Advanced Settings".

As described in Chapter 4, it is a good idea to draw in the plan elements — floors, walls, access points, etc. — in a certain order.
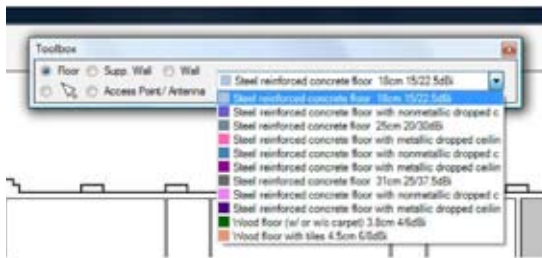
1. **Floor**: Select this tool to describe floors or ceilings. A floor element is a polygon with any number of sides. If there is an opening in a floor, such as a courtyard surrounded by the building, you must draw the floor accordingly. For detailed instructions, see Chapter 5. To draw a floor, click with the left mouse button at the corners of the desired area. At the last corner, click with the right mouse button to complete the polygon.

2. **Supp. Wall:** Supporting walls are elements of the building structure that are continuous through all floors. You should use the supporting wall tool wherever possible in order to minimize the number of plan elements and make the program's calculations significantly faster.

3. **Wall:** Use the Wall tool to draw partition walls that are present only in the selected floor. A wide variety of material types is available for partition walls, and the more exactly you draw all the walls that exist in your building, the better your planning will be. To draw a wall, click with the left mouse button where the wall begins and at each angle, then with the right mouse button where the wall ends.

4. **Arrow symbol:** Use the arrow tool to select elements in the plan. You can also edit the plan by dragging and dropping the drawing elements. To select several elements, press and hold the Ctrl key while you click on them. Clicking on a wall selects only one segment of it.

5. **Access Point/Antenna:** Use this tool to place an access point with its antenna in the plan. To insert an access point without an external antenna, use the antenna type "Generic Antenna a/b/g 7 dBi Omni." For all other antennas, select the desired type from the list. To add new antenna types to the library, see Chapter 5. You can also download additional antenna libraries from www.rf3d.com.

3.3 Drawing and Selecting Elements

First select the desired element in the Toolbox, then choose the appropriate type of material. Draw in plan elements using both the left and right mouse buttons: first use the left mouse button to mark corners, then the right mouse button to finish the element. Walls, floors and supporting walls are ordinarily drawn only in horizontal and vertical segments. But you can also draw diagonal segments at any angle simply by pressing the Ctrl key as you move the mouse. In this way you can draw walls and floors of any shape desired.

You can also select several walls at once, copy them to the Clipboard, and duplicate them in a different floor. Press and hold the Ctrl key while you select the desired elements by clicking on them with the left mouse button. Then select the menu command Edit/Copy (or press Ctrl+C). Choose the desired floor among the thumbnails in the left panel, then select the menu command Edit/Paste (or press Ctrl+V). If you make a mistake in editing the plan, use the menu command Edit/Undo (Ctrl+Z) to reverse the operation. To restore what you have undone, select Edit/Redo (Ctrl+Y).

3.4 The Simulation Tab

The Simulation tab provides a great deal of information and several configuration options during the simulation of your projected WLAN.

A. When you first start the RF3D WifiPlanner, the option "Automatic selective recompute" is activated. This means that the wireless network characteristics are recalculated automatically whenever you draw or move elements in the plan. This makes interactive planning easy. However, you may want to turn off automatic recomputing until you have completed at least a rough draft of your network plan. When the automatic recompute option is deactivated, you can click the "Tot.Recomp." button at any time to recompute the wireless network characteristics.

B. The box labeled **Info** contains the basic information about the current floor.

C. The "Resolution" control allows you to choose how precisely you want the WLAN characteristics to be computed. **Low** resolution uses yields a rough estimation of the wireless network characteristics, while **high** resolution results in very precise calculations. Note that the resolution setting has drastic effects on the computation time and the program's memory needs, however. Low resolution is therefore recommended for interactive planning work. Once you have completed your plan, you can use higher resolution to generate reports.

D. The **Network Load** control allows you to simulate various data traffic levels in your projected wireless network. This is very helpful since it allows you to design your network according to the types of applications it will support. Low network loads can be expected for example in warehousing and logistics applications, while office applications and Voice-over-IP usually generate higher traffic loads.

E. **View:** In this drop-down list you can choose the network characteristic that you want to display. The list contains the following views:

Log. Power

This is the received signal strength of the strongest access point at each location. Use this view to gauge the quality of your network coverage. A value of –70 dB or higher is sufficient. (Remember that, since the values in dB are negative, a higher value is one that is closer to zero.)

Log. SNR

This view shows the signal-to-noise ratio at each location, which reflects the effects of co-channel interference. A value of 10 dB or higher is good.

Data Rate

The data rate view shows the estimated attainable data rate at each location. This is a very useful prediction of how the projected network will actually perform. The display shows values between 1 and 54 Mbit/s. Higher data rates are better.

Interference

Interference is a major concern in wireless network planning. Interference is caused mainly by co-channel overlap with other access points. Reduce interference by selecting different channels for adjacent access points, or by reducing the output power of certain access points. This will reduce the size of the cell. How much interference you want to accept depends on your specific needs for redundancy and for throughput.

Redundancy (full version only)

Access point redundancy is important in areas that require continuous network availability even when local failures or system overloads occur. The RF3D WifiPlanner provides various views to help you plan access point redundancy. Each view simulates a certain scenario in which you can ensure that critical areas have adequate backup coverage.

Log. Power Reliability Level 1

This view displays the signal strength received from the second strongest access point at each location, assuming that the strongest access point is no longer working.

Log. Power Reliability Level 2

This view displays the signal strength received from the third strongest access point at each location, assuming that the strongest access point is no longer working.

Log. SNR Reliability Level 1

This view displays the signal-to-noise ratio at each location assuming that the strongest access point is no longer working.

Log. SNR Reliability Level 2

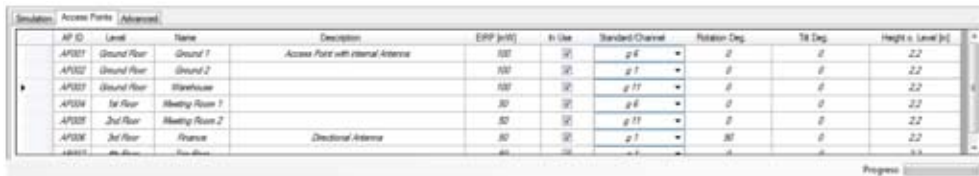This view displays the signal-to-noise ratio at each location assuming that the two strongest access points are no longer working.

F. The color scale indicates what numeric values correspond to the colors in the main display. You can modify the range and the number of gradations in the input fields below the color scale. This is practical when you would like to display finer distinctions in the plan.

3.5 The Access Point Tab

The **Access Points** tab lists all the access points currently planned, and allows you to modify their properties. The properties of each access point include a name and a description, the transmitter power, the channel setting, and the antenna orientation. The orientation is expressed in terms of rotation in the horizontal plane and inclination from the vertical. The rotation is entered in degrees, as on a compass, measured clockwise from the top of the plan: 0° indicates that the antenna is aimed "north", or towards the top of the plan; 90° is to the right, 180° towards the bottom, etc. In the Tilt field, a positive value indicates that the antenna is tilted upwards, and a negative value indicates the inclination downwards. 0° means that the antenna is in its normal orientation with respect to the horizontal plane.

3.6 Advanced Settings

In addition to walls and floors, enclosed spaces also contain many movable obstacles, such as people in offices and merchandise in warehouses, and objects that would be too difficult to draw in individually, such as furniture, shelves etc. For this reason, the **Advanced** tab allows you to set a global average attenuation factor to account for such objects in different kinds of spaces.

Select **Free Space** if there is no additional loss to be anticipated, as in outdoor areas such as parking lots or campus yards.

The default setting, **Factory/Warehouse**, factors in low to moderate loss for low-density spaces such as warehouses.

The Office setting adds moderate to high attenuation to account for the furniture and persons present in typical office environments.

4 Planning Wireless Networks

4.1 What Application Is Intended?

To plan a wireless network, start by determining which applications will eventually be transported over the projected network. There are critical differences between applications that require greater redundancy, but only low data traffic, such as warehousing and logistics, and applications that require high bandwidth, such as voice-over-WLAN.

For a warehouse application, for example, you should design the wireless cells larger and tolerate a higher level of interference. This increases reliability, since the second nearest access point to a given location will probably be usable in case the nearest one fails. To change the size of the wireless cells, click the Access Points tab and adjust the transmitter power of each access point. The higher the transmitter power of an access point, the larger the cell it covers.

Inversely, if you are designing a network for voice-over-WLAN, you should plan smaller cells. This is because interference should be minimized for voice-over-WLAN, since voice packets that are lost due to interference are not resent, as lost packets in other applications are. Thus interference affects voice fidelity, and in extreme cases can make voice communication impossible.

4.2 Entering Environmental Factors

In planning a wireless network with the RF3D WifiPlanner, you should follow a certain sequence of steps in order to achieve your objective quickly and easily. Furthermore, performing the steps in the order described here minimizes the computation involved, and hence the processing time as well. The process can be divided into five simple steps:

| Import Floor Plans/Maps | Define Building Structure | Place Access Points & Antennas | Optimize Network Planning | Generate Report / Printing |

Once you have imported all the building plans as described in Section 3.1, you should first draw in the floors in each level. If all the floors in the building are of the same shape and the same materials, you can copy the first floor to all the other plans using the menu command **Edit/Paste Floor to Other Levels.**

Hint: *Before you begin drawing in all the building elements, you can turn off the Automatic selective recompute function as described in Section 3.4. This will save processor time, since otherwise the RF3D WifiPlanner recomputes the wireless network characteristics each time you draw an element of the building plan.*

There are two different kinds of walls in the RF3D WifiPlanner: supporting walls, drawn with the **Supp. Wall** tool in the Toolbox, and partition walls, drawn with the **Wall** tool. When you draw a supporting wall, it is automatically inserted in all levels of the building, and the RF3D WifiPlanner treats it as a single element. You should use supporting walls to represent all the walls in your building that have the same position and material composition in all levels. This can significantly reduce the processing time in comparison to normal walls drawn in on each level separately, since there are fewer elements to be processed by the computing algorithms.

After you have drawn in all the supporting walls, you should draw in the partition walls on each level.

4.3 Positioning Access Points

Now that you have drawn all the elements of the building, you can begin to design the WLAN itself by positioning the access points and defining their properties. Because RF3D WifiPlanner considers each access point in combination with its antenna, you should know what type of antenna you are thinking of using when you select the Access Point tool in the Toolbox. If you plan to use an access point without an external antenna, you can select one of the "Generic" types. RF3D WifiPlanner has a library containing a number of external antenna definitions. When you use a directional antenna, you can aim it in your plan as described in Section 3.5.
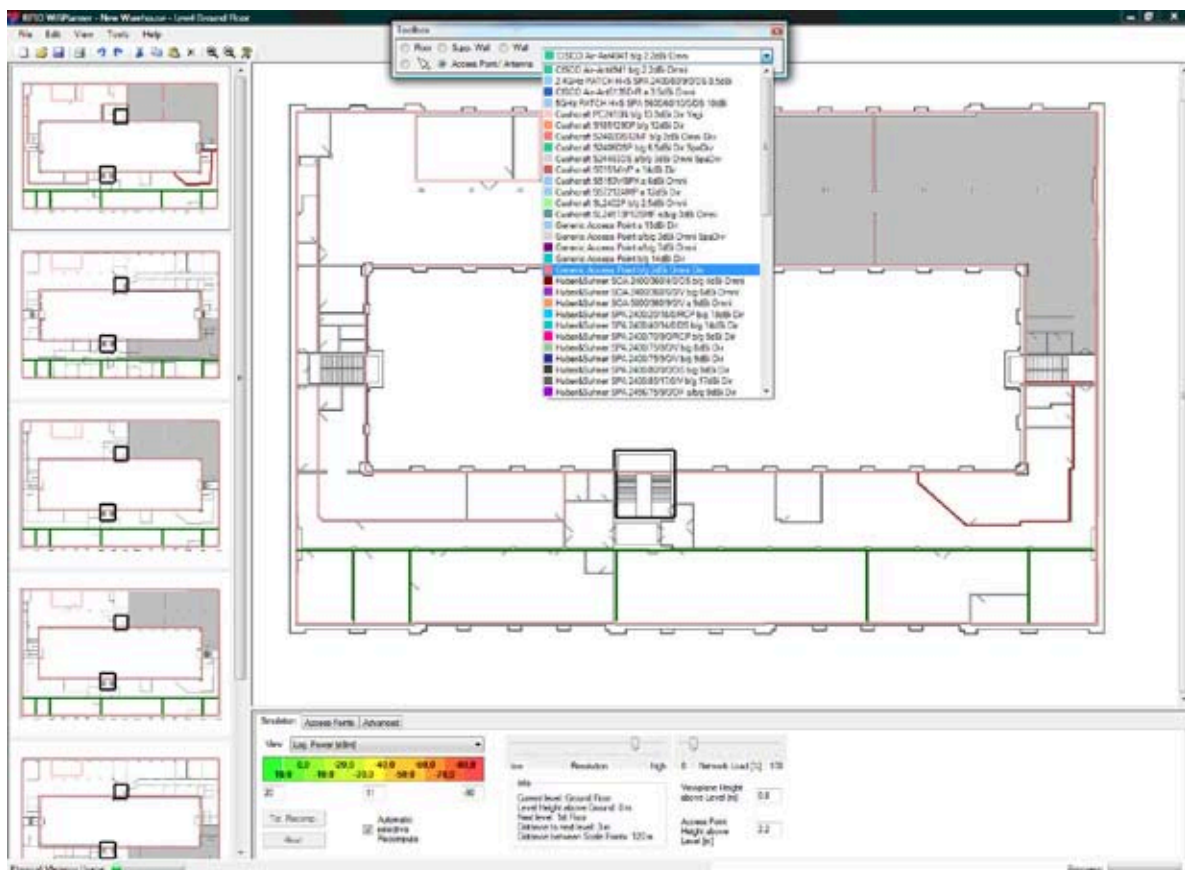
Select the desired antenna in the Toolbox list.

When you begin to position your access points, you should make sure that sufficient signal power can be received everywhere in the building. Sufficient signal power generally means a value of –60 dBM or better. Another thing to consider in your planning is interference. Primarily, this means avoiding co-channel interference, which occurs when adjacent access points use overlapping channel settings.

Sufficient signal power (–60 dBm or better) throughout the building..

Start your planning with the access points in the lowest level, and use a cellular struc-
ture as described in Section 2.3. Set the communication channels of the access points
in conformance with national restrictions. When you continue with the access points
in the other levels, remember that access points transmit through floors and ceilings.
Your cellular structure should therefore take into account the access points located
above and below one another.
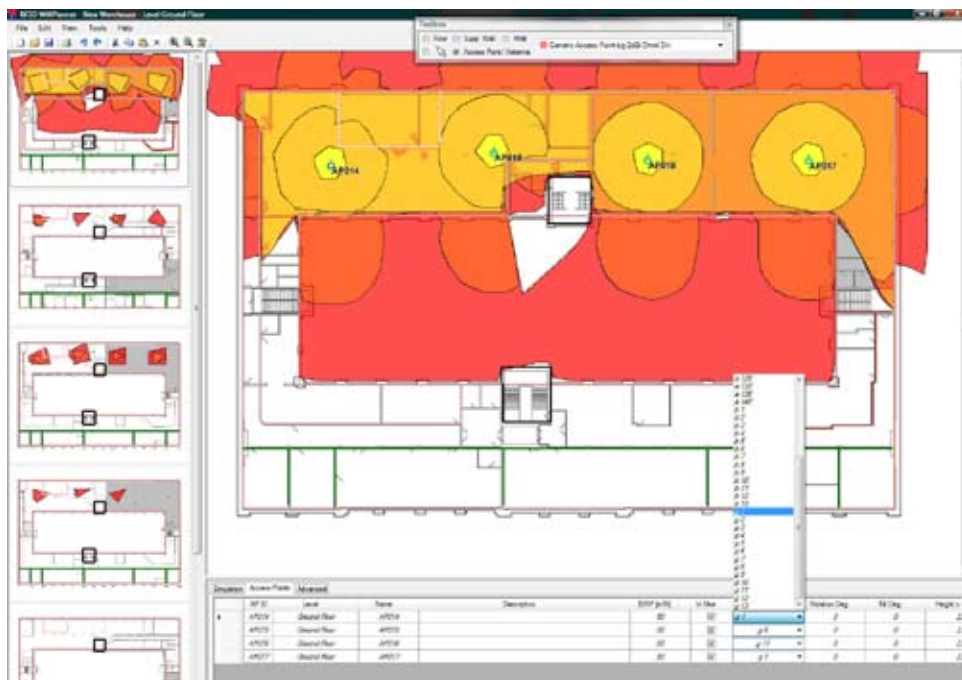
Setting the communication channels for all access points. Avoid channel overlap.

When you choose channels for the access points, it can be helpful to switch the view mode from signal power to data rate, because the data rate view reflects any adverse effects of co-channel or near-channel interference due to channel settings.

Checking the results of access point settings in the Data Rate view.

4.4 Optimizing Wireless Networks

When you have finished planning wireless signal coverage for the building, you can begin to optimize the network. You can do this in several ways, using the RF3D WifiPlanner's various views on the Simulation tab, such as data rate, interference, etc. One approach is to display the expected data rates. The data rate view reflects all radio effects, including interference, signal-to-noise ratio and network traffic loads. Gaps or areas with lower data rates indicate room for improvement. To analyze the causes of lower data rates, you can use the interference or SNR views. The problems can be alleviated by changing the access point settings.

When you are satisfied with your basic WLAN plan, you can then simulate its behavior in case of faults, such as access point failures. Do this by deactivating individual access points on the Access Points tab. A better way, however, is to use the "Log. Power Reliability Level 1" view. In this view, RF3D WifiPlanner displays the signal power that would be received at each location in the plan if the strongest access point for that location had failed. For high-reliability applications, gaps in the coverage in this view can be a problem. You can fill such gaps by adding access points.

There is always more than one way to design a wireless network. The need for a reliable or "high-availability" network is often difficult to reconcile with the need to ensure high data rates by avoiding interference. You will find, however, that networks you have designed using RF3D WifiPlanner are efficient, optimum solutions.

5 Advanced Settings

5.1 Editing Wall and Floor Libraries

he properties and settings of wall and floor materials are stored in the library. You can easily edit and expand this library. Each type of wall or floor is saved in a separate XML file. These files are contained in the folder RF3DWifiPlanner/WallsFloors.

The names of the wall and floor files must follow certain rules in order to be recognized by the RF3D WifiPlanner program. Example: ft_003_6-_Brick_7_18dB. The file name must begin with 'ft' or 'm' to indicate whether this wall or floor is defined in feet or in meters. The wall or floor is then available in the Toolbox only when the same measurement unit is selected in the program options. The next part of the file name after the measurement unit abbreviation is an underscore followed by a three-digit number. This number determines the position at which the given wall or floor type appears in the toolbox list. After another underscore comes the name you want to use for this wall or floor type.

The best way to create a wall or floor type is to find a file that defines a similar, existing type, open it in Notepad, and save it under a new name before editing its contents. The lines you can edit are explained with examples below.
The Type line defines the name displayed in the Toolbox.
<Type id="ref-4">6" **Brick 7/18dB**</Type>

The DampA_dB line indicates the signal attenuation through such a wall or floor in dB in the 5 GHz band used for 802.11 a and h networks.
<DampA_dB>**7**</DampA_dB>

The DampBG_dB line indicates the signal attenuation through such a wall or floor in dB in the 2.4 GHz band used for 802.11 b and g networks.
<DampBG_dB>**18**</DampBG_dB>

The GaugeFeet line indicates the thickness of the wall or floor in feet. If you enter a non-zero value here, you should enter zero in the GaugeMeter line below.
<GaugeFeet>**0.5**</GaugeFeet>

The GaugeMeter line indicates the thickness of the wall or floor in meters. If you enter a non-zero value here, you should enter zero in the GaugeFeet line above.
<GaugeMeter>**0**</GaugeMeter>

The knownColor line defines the color in which you will draw the wall or floor in the level plans. For permissible color names, see the table in Appendix c.
<knownColor>**142**</knownColor>

The IsFloor line determines whether the building element described in this file is a wall or a floor. If IsFloor is **true**, it's a floor. If IsFloor is **false**, the file describes a wall.
<IsFloor>**false**</IsFloor>

If you have edited a copy of an existing library file, you must leave all other parts of the file unchanged. Otherwise, the program may behave unexpectedly.

5.2 Editing the Access Point/Antenna Library

The antenna library, like the wall and floor library, is stored in the form of individual files for each antenna type. These files are contained in the folder RF3DWifiPlanner/Antennas, and can be edited with Notepad. The best way to create an antenna type is to find the file that defines a similar, existing type, open it in Notepad, and save it under a new name before editing its contents.

Any antenna can be defined for the 2.4 GHz band, the 5 GHz band, or both bands.

The example used in the following explanation defines an antenna for the 2.4 GHz band only.

An antenna file describes the antenna's radiation pattern in terms of its horizontal and vertical cross-sections, as well as some additional parameters. The antenna's radiation pattern must be described for the antenna's normal installation orientation. Theta (θ) represents the upward elevation angle from the horizontal plane in degrees. Negative values indicate downward elevation. Phi (φ) designates the azimuth angle in degrees — that is, the rotational angle in the horizontal plane, where positive values represent a clockwise rotation from 12 o'clock. Directional antennas should be described so that their greatest gain is at phi=0° and theta=0°.

You can enter as many directional gain values (data points) as you want, and the number of data points only has to be entered in a few places, as described below. The data points you specify can also be at any angles desired, and their distribution can vary within an antenna file. However, both the precision of the program display and the time required to recompute and refresh the display increase as the number of data points increases.

In computing the antenna gain, the program adds the directional gain in dBi to the global gain (in the example, 4 dBi). This means that the directional gain value should be normalized to 0 dBi.

Please note that the decimal point must be a period ('.'). Note too that the tags and values are case-sensitive.

The Type line contains the text displayed for this antenna type in the toolbox.

```
<Type id="ref-4">SOA 2400/360/4/0/DS</Type>
```

The TypeShort line is not currently used in the program. You can use it for your comments.

```
<TypeShort id="ref-5">Bild 6, 139.26.0044</TypeShort>
```

The Gain_dB_2_4GHz line defines the antenna gain in the 2.4 GHz band.

```
<Gain_dB_2_4GHz>4</Gain_dB_2_4GHz>
```

The IsZIsotropic_2_4GHz line indicates whether the antenna is approximately omnidirectional in the horizontal plane in the 2.4 GHz band. The value true indicates that its radiation pattern is roughly rotationally symmetric with respect to the vertical axis.

```
<IsZIsotropic_2_4GHz>true</IsZIsotropic_2_4GHz>
```

The Gain_dB_5GHz line defines the antenna gain in the 5 GHz band.

```
<Gain_dB_5GHz>0</Gain_dB_5GHz>
```

The IsZIsotropic_5GHz line indicates whether the antenna is approximately omnidirectional in the horizontal plane in the 5 GHz band. The value true indicates that its radiation pattern is roughly rotationally symmetric with respect to the vertical axis.

```
<IsZIsotropic_5GHz>false</IsZIsotropic_5GHz>
```

The Is2_4GHz line specifies whether the antenna can be used in the 2.4 GHz band.

```
<Is2_4GHz>true</Is2_4GHz>
```

The Is5GHz line specifies whether the antenna can be used in the 5 GHz band.

```
<Is5GHz>false</Is5GHz>
```

The next few lines are references to data defined later in the file.
Do not change these lines!

```
<Phi_Deg_2_4GHz href="#ref-6"/>
<Theta_Deg_2_4GHz href="#ref-7"/>
<Phi_dBi_2_4GHz href="#ref-8"/>
<Theta_dBi_2_4GHz href="#ref-9"/>
<Phi_Deg_5GHz href="#ref-10"/>
<Theta_Deg_5GHz href="#ref-11"/>
<Phi_dBi_5GHz href="#ref-12"/>
<Theta_dBi_5GHz href="#ref-13"/>
<Col>
<name xsi:null="1"/>
<value>0</value>
```

The knownColor line specifies the color in which the given antenna is displayed in the level plans. For the permissible color values, see Appendix C.

```
<knownColor>59</knownColor>
<state>1</state>
</Col>
</a1:AntennaType>
```

The array, or list of values, which follows contains phi values (angle measures in degrees) for 72 data points at 2.4 GHz. If you use a different number of data points, replace the "72" in this line with the number of data points you want to define.

```
<SOAP-ENC:Array id="ref-6" SOAP-ENC:arrayType="xsd:float[72]">
<item>-180</item>
<item>-175</item>
<item>-170</item>
.
.
.
<item>165</item>
<item>170</item>
<item>175</item>
</SOAP-ENC:Array>
```

The next array, with the attribute id="ref-7", contains theta values (angle measures in degrees) for 72 data points at 2.4 GHz.

```
<SOAP-ENC:Array id="ref-7" SOAP-ENC:arrayType="xsd:float[72]">
<item>-90</item>
<item>-85</item>
<item>-80</item>
.
.
.
<item>255</item>
<item>260</item>
<item>265</item>
</SOAP-ENC:Array>
```

The next array, with the attribute id="ref-8", contains gain values in dBi for the values of phi listed above, representing 72 data points at 2.4 GHz.

```
<SOAP-ENC:Array id="ref-8" SOAP-ENC:arrayType="xsd:float[72]">
<item>-2.381</item>
<item>-2.399</item>
<item>-2.388</item>
.
.
.
<item>-2.005</item>
<item>-2.175</item>
<item>-2.303</item>
</SOAP-ENC:Array>
```

The next array, with the attribute id="ref-9", contains gain values in dBi for the values of theta listed above, representing 72 data points at 2.4 GHz.

```
<SOAP-ENC:Array id="ref-9" SOAP-ENC:arrayType="xsd:float[72]">
<item>-16.683</item>
<item>-12.24</item>
<item>-7.157</item>
.
.
.
<item>-5.032</item>
<item>-7.721</item>
<item>-12.307</item>
</SOAP-ENC:Array>
```

The next array, with the attribute id="ref-10", contains a phi value (angle measure in degrees) for one data point at 5 GHz. This array is rudimentary, since the antenna is not used for the 5 GHz band.

```
<SOAP-ENC:Array id="ref-10" SOAP-ENC:arrayType="xsd:float[1]">
<item>0</item>
</SOAP-ENC:Array>
```

The next array, with the attribute id="ref-11", contains a theta value (angle measure in degrees) for one data point at 5 GHz.

```
<SOAP-ENC:Array id="ref-11" SOAP-ENC:arrayType="xsd:float[1]">
<item>0</item>
</SOAP-ENC:Array>
```

The next array, with the attribute id="ref-12", contains a gain value in dBi for the value of phi listed above, representing one data point at 5 GHz.

```
<SOAP-ENC:Array id="ref-12" SOAP-ENC:arrayType="xsd:float[1]">
<item>0</item>
</SOAP-ENC:Array>
```

The next array, with the attribute id="ref-13", contains a gain value in dBi for the value of theta listed above, representing one data point at 5 GHz.

```
<SOAP-ENC:Array id="ref-13" SOAP-ENC:arrayType="xsd:float[1]">
<item>0</item>
</SOAP-ENC:Array>
```

All other lines in the file must remain unchanged.

5.3 Options and Settings

To adjust other program settings, select the the menu command **Tools/Options**. The **Country** option group allows you to set appropriate parameters for the country where you are located. The **Geometry** option group lets you specify default values for the height of new access points above the floor, the vertical distance between floors, etc. The options in the **Graphics** group allow you to set display properties, and the **Physics** option group allows you to set basic physical parameters for radio signal calculations. Finally, the options in the **Printer** group allow you to control how your planning diagrams are printed.

To change any setting, click on the existing value. A description of the parameter appears in the box below the options list. After you have changed one or more of these settings, you must exit the program and restart it for your new settings to take effect. To reset all options to their original values, click the "Defaults" button.
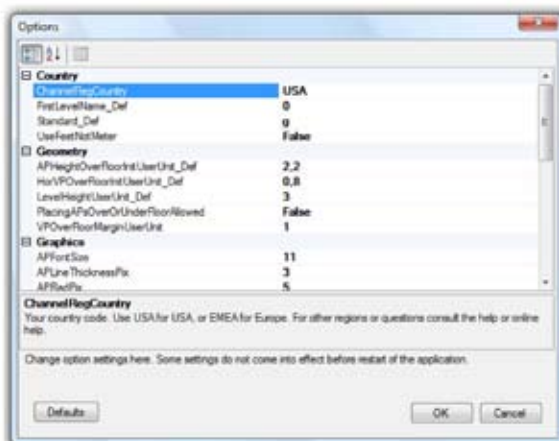
5.4 Floors with Openings

Some buildings have open areas in the floors, such as inner courtyards. Such areas must be left open in your plans as well in order for interference to be computed correctly. You can draw floors with open areas as follows: First, draw some of the edges of the floor along the outer walls, but do not complete the polygon. Then draw the edges of the open space in the interior.
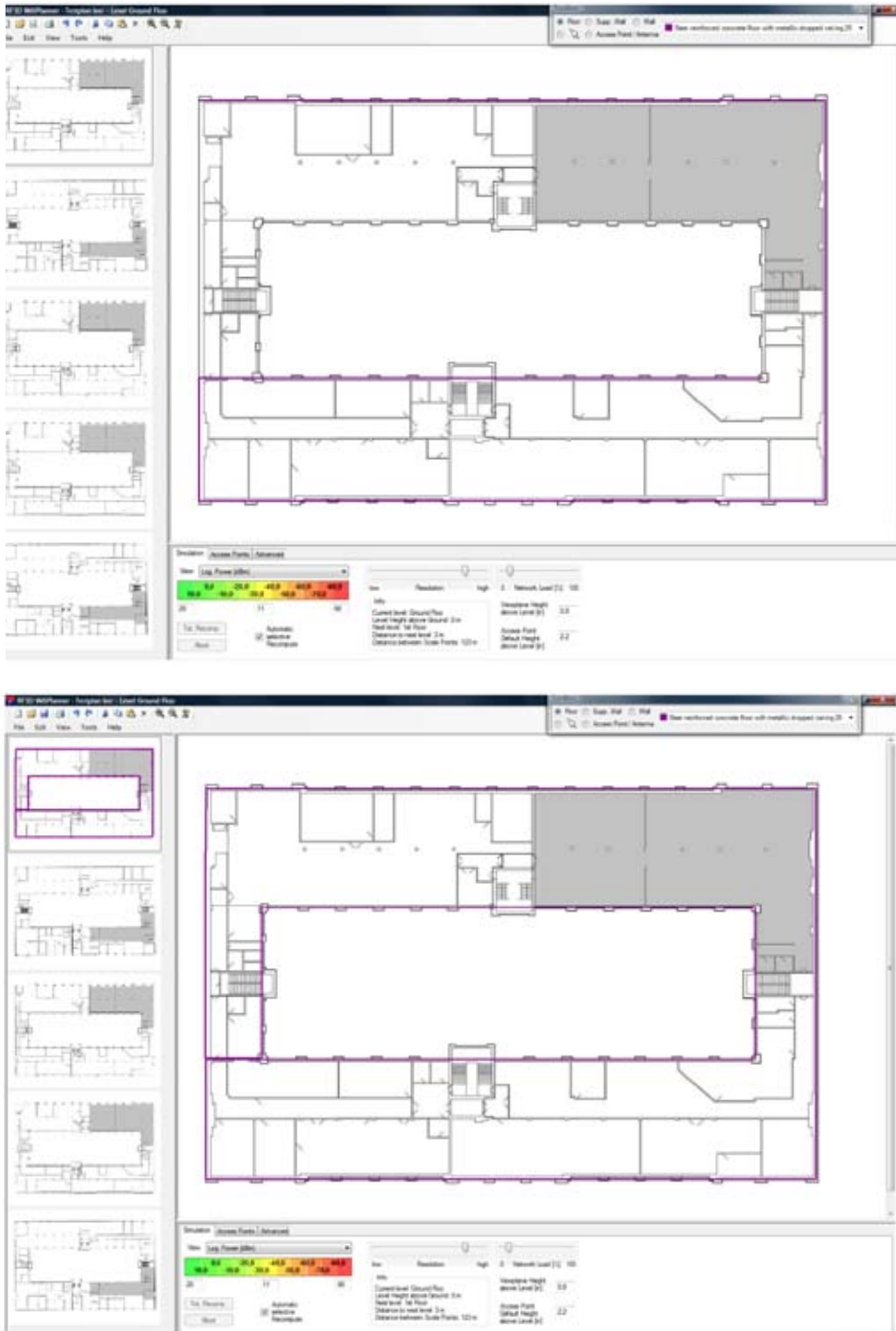
In this way you can draw the floor in one piece while leaving an interior area open.

5.5 Split-Level Buildings

To represent buildings with split levels, import a drawing for each partial level and draw in partial floors for the existing floor areas. Remember, though, that walls you draw in on a lower level extend only to the height of the next higher level, even if they do not meet a floor there. If your building has walls that extend through a split level, you must draw them on the lower level and again in the unfloored space on the next higher, partially floored level.

Appendix A The Antenna Library

Antenna Library

Hier finden Sie die Antennendiagramme für die in RF3D WifiPlanner hinterlegten generischen Antennentypen.

Generic Access Point w/ Dipole Ant a/b/g 2dBi
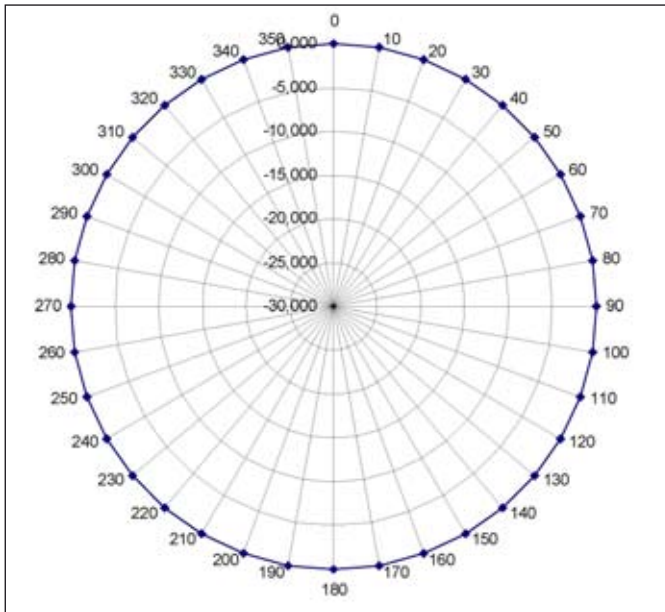
Horizontal section of a/b/g Net
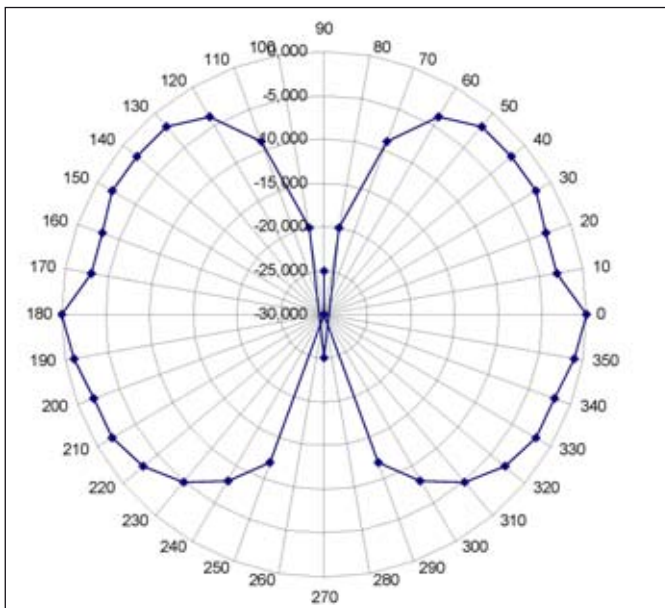
Vertical section of a/b/g Net

Generic Antenna a/b/g 7dBi Omni
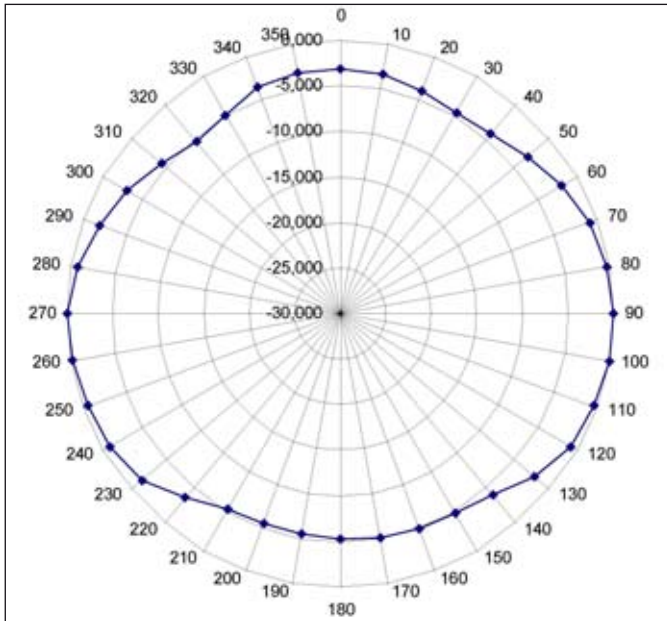
Horizontal section of b/g Net
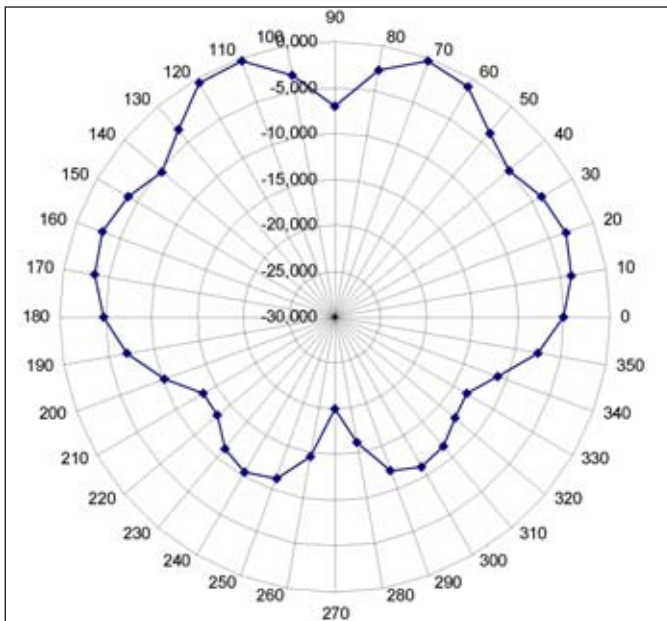
Vertical section of b/g Net
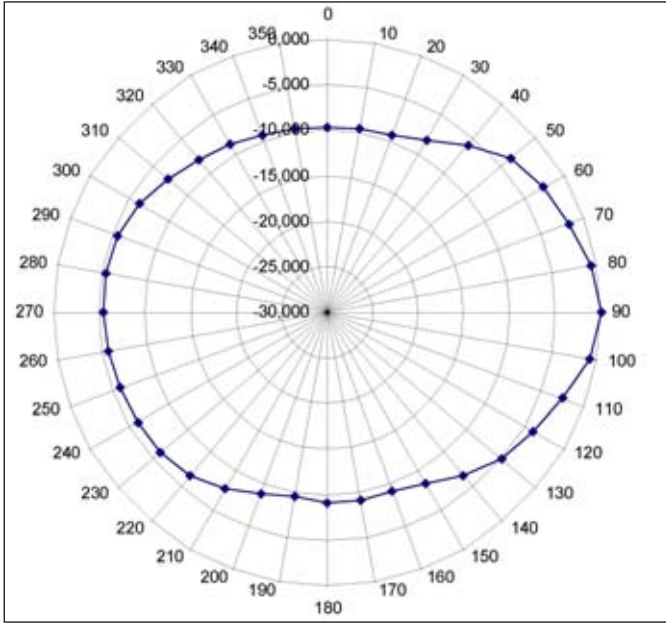
Horizontal section of a/h Net
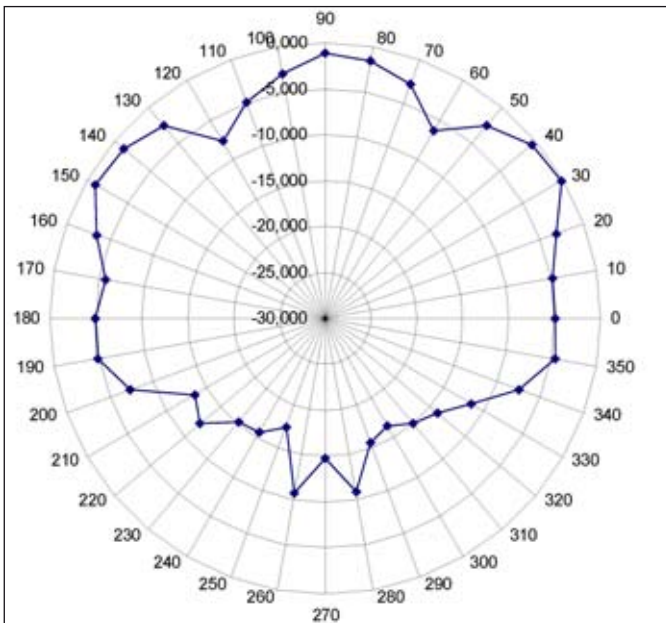
Vertical section of a/h Net

RF3D WifiPlanner

Generic Antenna a/b/g 8dBi directional

Horizontal section of a/b/g Net

Vertical section of a/b/g Net

Generic Antenna a/b/g 13,9 dBi Directional Yagi

Horizontal section of a/b/g Net

Vertical section of a/b/g Net

Generic Antenna a/b/g 18 dBi Directional

Horizontal section of a/b/g Net

Vertical section of a/b/g Net

Appendix B The Wall and Floor Library

List of wall & floor materials measurement unit: feet

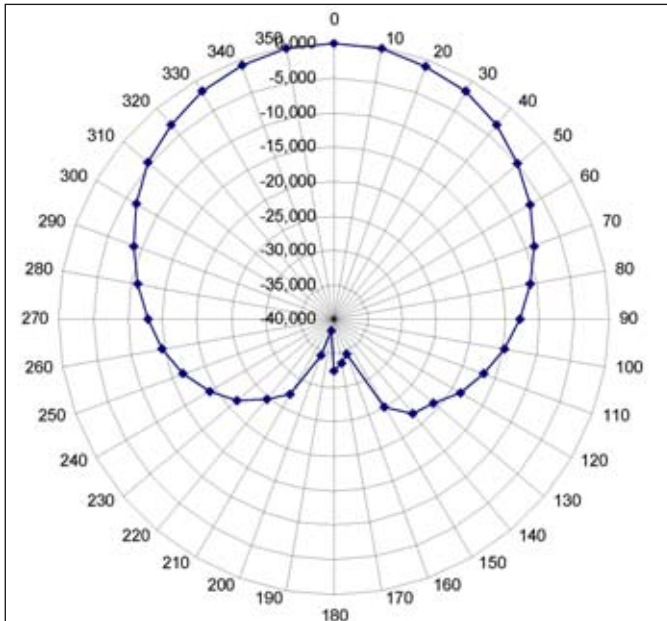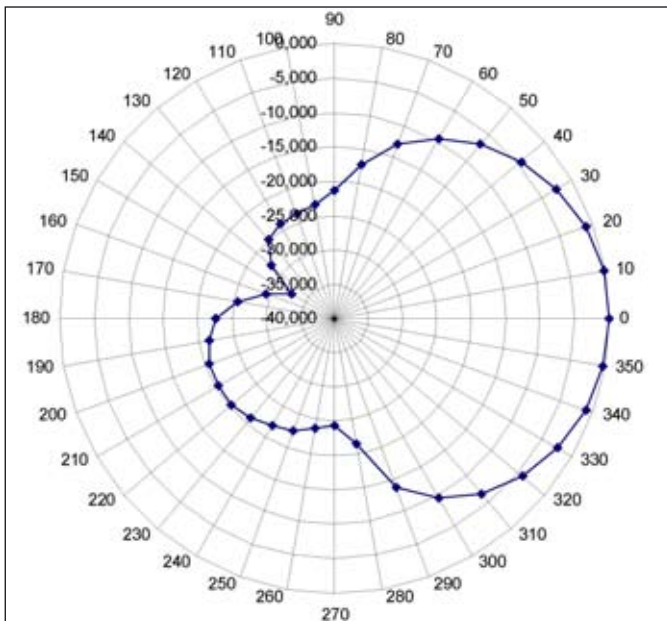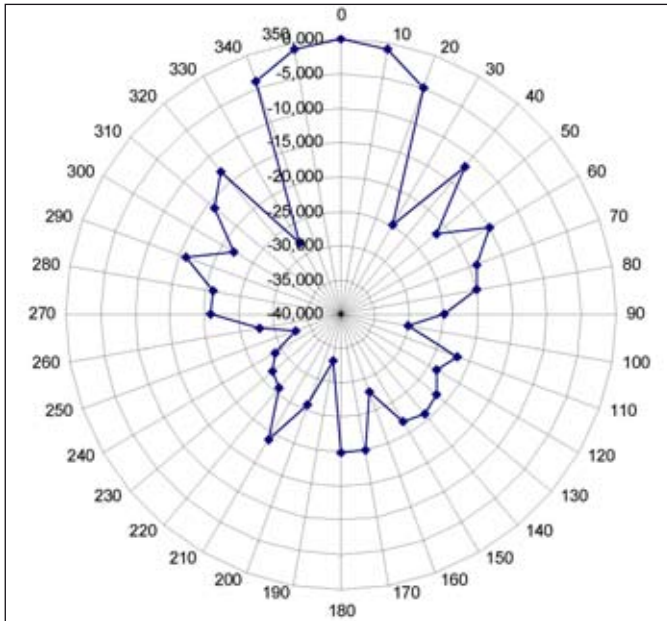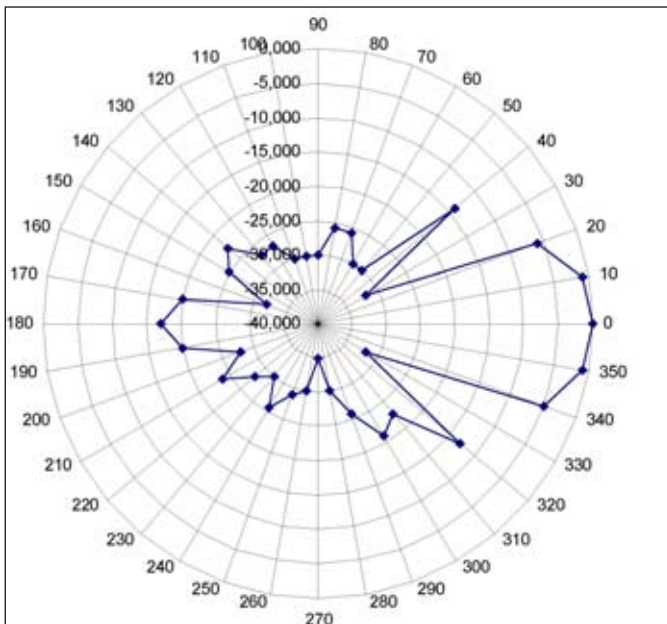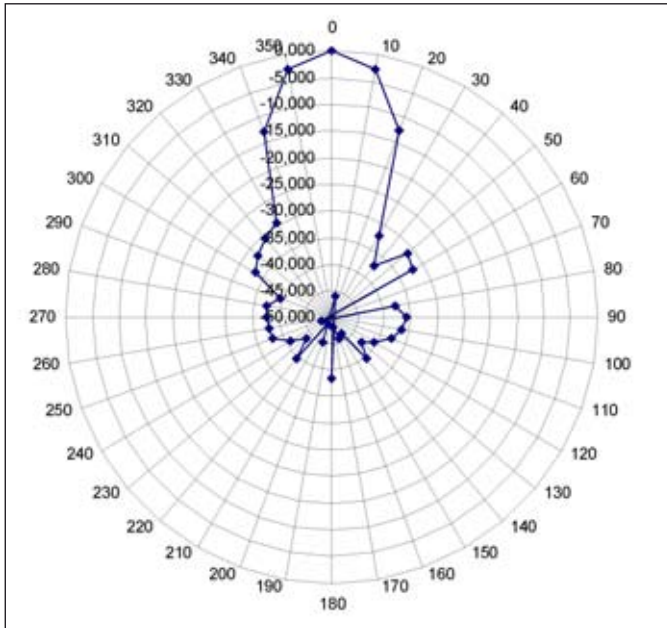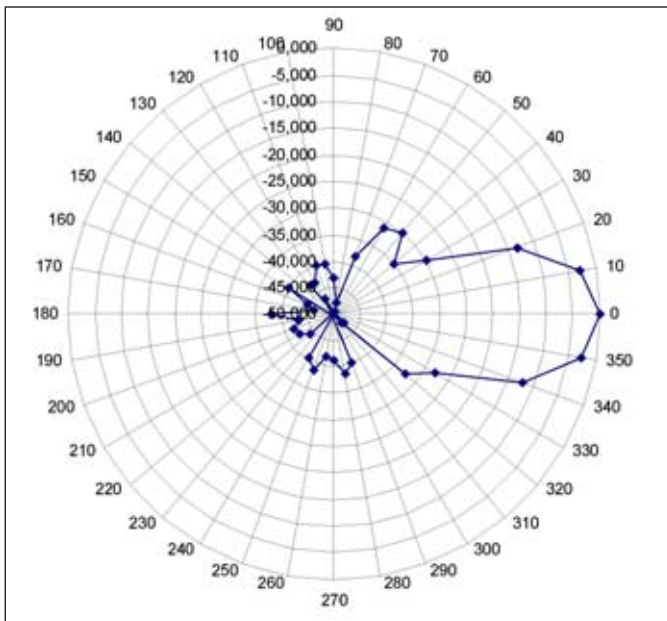| Floor / Wall	Att. 2.4 GHz (dB)	Att. 5 GHz (dB)	Thick-ness (in)	RF3D Toolbox Text	Nr RF3D	Nr RF3D Lite	Color-Code	Discribtion
Wall	16,0	24,0	8	8" Concrete Block w/ Steel 16/24dB	1	1	144	Concrete block, when reinforced with concrete columns and tie beams, is a very common building material for the load-bearing walls of buildings, in what is termed CBS construction for Concrete Block Structure.
Wall	22,0	33,0	12	12" Concrete Block w/ Steel 22/33dB	2	2	146	Concrete block, when reinforced with concrete columns and tie beams, is a very common building material for the load-bearing walls of buildings, in what is termed CBS construction for Concrete Block Structure.
Wall	7,0	18,0	6	6" Brick 7/18dB	3	3	142	Brick wall
Wall	10,0	25,0	10	10" Brick 10/25dB	4		83	Brick wall
Wall	13,0	32,5	20	20" Brick 13/32.5dB	5		39	Brick wall
Wall	17,0	25,5	8	8" Concrete w/Steel 17/25dB	6	6	102	Steel reinforced concrete wall
Wall	24,0	36,0	12	12" Concrete w/Steel 24/36dB	7	7	101	Steel reinforced concrete wall
Wall	33,0	49,5	16	16" Concrete w/Steel 33/50dB	8	8	68	Steel reinforced concrete wall
Wall	2,0	3,0	8	8" Light-Weight Concrete w/Steel 2/3dB	9		61	Light-weight concrete wall
Wall	0,8	0,8	N/A	5" Drywall (2 sides) Over Framing .8/0.8dB	10	10	97	Drywall, also commonly known as gypsum board, plaster-board. A drywall panel is made of a paper liner wrapped around an inner core made primarily from gypsum plaster.
Wall	0,8	0,8	N/A	7" Drywall (2 sides) Over Framing .8/0.8dB	11	11	92	Drywall, also commonly known as gypsum board, plaster-board. A drywall panel is made of a paper liner wrapped around an inner core made primarily from gypsum plaster.
Wall	1,5	1,5	N/A	4" Plywood (1 side) Over Framing 1.5/1.5dB	12		80	One layer Plywood wall
Wall	3,0	3,0	N/A	4.5" Plywood (2 sides) Over Framing 3/3dB	13		53	Two layer Plywood wall
Wall	15,0	15,0	1	1" Stucco Over 2x4 Wood or Steel 15/15dB	14	14	95	Modern Stucco usually consists of 1 layer of wire lath and 2 layers of portland cement-based plaster
Wall	3,0	4,5	1	Window-1" Dual Glazed 3/4.5dB	15		91	Glass window
Wall	28,0	42,0	1	Window-1" IR-blocking 28/42dB	16		69	Infrared blocking window
Wall	2,0	3,0		2"-4" Office divider glass/wood 2/3dB	17		127	Office divider
Wall	1,0	1,5	2	2" Office cubical 1/1.5dB	18		128	Office divider
Wall	1,5	2,3	36	Shelf/Rack 3` 1.5/2.25dB	19		56	Shelf/rack
Wall	3,0	4,5	72	Shelf/Rack 6` 3/4.5dB	20		125	Shelf/rack
Wall	4,0	6,0	96	Shelf/Rack 8` 4/6dB	21		126	Shelf/rack
Wall	30,0	45,0		Wall or Ceiling-Corrugated Steel 30/45dB	22		62	Metal wall sheeting in the form of Corrugated galvanized iron
Wall	30,0	45,0		Elevator shaft 30/45dB	23	23	35	Elevator shaft
Floor	17,0	25,5	8	8" Concrete w/Steel 17/25.5dB	100	100	102	Steel reinforced concrete floors
Floor	18,0	27,0	8	8" Concrete/Steel w/ Nonmetallic Drop Ceiling 18/27dB	101	101	152	Steel reinforced concrete floors with nonmetallic dropped ceiling
Floor	27,0	40,0	8	8" Concrete/Steel w/ Metallic Drop Ceiling 27/40dB	102		82	Steel reinforced concrete floors with metallic dropped ceiling
Floor	20,0	30,0	10	10" Concrete w/Steel 20/30dB	103	103	101	Steel reinforced concrete floors
Floor	21,0	31,5	10	10" Concrete/Steel w/ Nonmetallic Drop Ceiling 21/31dB	104	104	156	Steel reinforced concrete floors with nonmetallic dropped ceiling

Floor	30,0	45,0	10	10" Concrete/Steel w/ Metallic Drop Ceiling 30/45dB	105		55	Steel reinforced concrete floors with metallic dropped ceiling
Floor	24,0	36,0	12	12" Concrete w/Steel 24/36dB	106	106	68	Steel reinforced concrete floors
Floor	25,0	37,5	12	12" Concrete/Steel w/ Nonmetallic Drop Ceiling 25/37dB	107	107	162	Steel reinforced concrete floors with nonmetallic dropped ceiling
Floor	34,0	51,0	12	12" Concrete/Steel w/ Metallic Drop Ceiling 34/51dB	108		84	Steel reinforced concrete floors with metallic dropped ceiling
Floor	4,0	6,0	1,5	1.5" Wood Flooring w/ Subfloor 4/6dB	120		53	Wood Flooring with subfloor
Floor	6,0	8,0	1,5	1.5" Tile w/ Subfloor 6/8dB	121		60	Tile with subfloors

List of wall & floor materials measurement unit: meter

Floor / Wall	Att. 2.4 GHz (dB)	Att. 5 GHz (dB)	(Mean) Thickness cm	RF3D Text	Nr	Lite Nr	Color-Code	Comment
Wall	8	20	18	Brick wall 18cm 8/20dB	1	1	142	Brick wall
Wall	10	25	25	Brick wall 25cm 10/25dB	2	2	83	Brick wall
Wall	13	32,5	50	Brick wall 50cm 13/32.5dB	3	3	39	Brick wall
Wall	15	22,5	18	Steel reinforced concrete wall 18cm 15/22.5dB	4	4	102	Steel reinforced concrete wall
Wall	20	30	25	Steel reinforced concrete wall 25cm 20/30dB	5	5	101	Steel reinforced concrete wall
Wall	25	37,5	31	Steel reinforced concrete wall 31cm 25/37.5dB	6	6	68	Steel reinforced concrete wall
Wall	2	3	18	Light-Weight concrete/gas concrete 18cm 2/3dB	7		61	Light-weight concrete wall
Wall	0,8	0,8	N/A	Dry wall/1.5cm plasterboard each side 0.8/0.8dB	8	8	97	Drywall, also commonly known as gypsum board, plasterboard. A drywall panel is made of a paper liner wrapped around an inner core made primarily from gypsum plaster.
Wall	1,6	1,6	N/A	Dry wall/3.0 cm plasterboard at each side 1.6/1.6dB	9	9	92	Drywall, also commonly known as gypsum board, plasterboard. A drywall panel is made of a paper liner wrapped around an inner core made primarily from gypsum plaster.
Wall	4	6	3,8	Wood Wall 3.8cm 4/6dB	10		80	One layer wood wall
Wall	8	12	N/A	Wood Wall/3.8cm each side 8/12dB	11		53	Two layer wood wall
Wall	15	15	2,6	Stucco wall 2.6cm 15/15dB	12		95	Modern Stucco usually consists of 1 layer of wire lath and 2 layers of portland cement-based plaster
Wall	3	4,5	3	Double Glazed Window 3cm 3/4.5dB	14		91	Glass window
Wall	28	42	3	IR-blocking Window 3cm 28/42dB	15		69	Infrared blocking window
Wall	2	3	N/A	Office divider glass/wood 5-10cm 2/3dB	16		127	Office divider
Wall	1	1,5	5	Office cubical 5cm 1/1.5dB	17		128	Office divider
Wall	1,6	2,4	100	High rise rack 100cm 1.6/2.4dB	18		56	High rise rack approx 1m thick
Wall	30	45	N/A	Profiled sheeting 30/45dB	18		62	Metal wall sheeting in the form of Corrugated galvanized iron
Wall	30	45	N/A	Elevator shaft 30/45dB	20	20	35	Elevator shaft
Floor	15	22,5	18	Steel reinforced concrete floor 18cm 15/22.5dB	100	100	102	Steel reinforced concrete floors
Floor	16	24	18	Srcf with nonmetallic dropped ceiling 18cm 16/24dB	101	101	152	Steel reinforced concrete floors with nonmetallic dropped ceiling
Floor	25	37,5	18	Srcf with metallic dropped ceiling 18cm 25/37.5dB	102		82	Steel reinforced concrete floors with metallic dropped ceiling
Floor	20	30	25	Steel reinforced concrete floor 25cm 20/30dB	103	103	101	Steel reinforced concrete floors
Floor	21	31,5	25	Srcf with nonmetallic dropped ceiling 25cm 21/31.5dB	104	104	156	Steel reinforced concrete floors with nonmetallic dropped ceiling
Floor	30	45	25	Srcf with metallic dropped ceiling 25cm 30/45dB	105		55	Steel reinforced concrete floors with metallic dropped ceiling
Floor	25	37,5	31	Steel reinforced concrete floor 31cm 25/37.5dB	106	106	68	Steel reinforced concrete floors
Floor	26	39	31	Srcf with nonmetallic dropped ceiling 31cm 26/39dB	107	107	162	Steel reinforced concrete floors with nonmetallic dropped ceiling
Floor	35	52,5	31	Srcf with metallic dropped ceiling 31cm 35/52.5dB	108		84	Steel reinforced concrete floors with metallic dropped ceiling
Floor	4	6	3,8	Wood floor (w/ or w/o carpet) 3.8cm 4/6dB	120		53	Wood Flooring with carpet
Floor	6	8	4,5	Wood floor with tiles 4.5cm 6/8dB	121		60	Wood Flooring with tiles

Appendix C Table of Colors

Color	knownColor	R	G	B	A
Aqua	30	0	255	255	255
Aquamarine	31	127	255	212	255
Black	35	0	0	0	255
BlanchedAlmond	36	255	235	205	255
Blue	37	0	0	255	255
BlueViolet	38	138	43	226	255
Brown	39	165	42	42	255
BurlyWood	40	222	184	135	255
CadetBlue	41	95	158	160	255
Chartreuse	42	127	255	0	255
Chocolate	43	210	105	30	255
Coral	44	255	127	80	255
CornflowerBlue	45	100	149	237	255
Crimson	47	220	20	60	255
Cyan	48	0	255	255	255
DarkBlue	49	0	0	139	255
DarkCyan	50	0	139	139	255
DarkGoldenrod	51	184	134	11	255
DarkGray	52	169	169	169	255
DarkGreen	53	0	100	0	255
DarkKhaki	54	189	183	107	255
DarkMagenta	55	139	0	139	255
DarkOliveGreen	56	85	107	47	255
DarkOrange	57	255	140	0	255
DarkOrchid	58	153	50	204	255
DarkRed	59	139	0	0	255
DarkSalmon	60	233	150	122	255
DarkSeaGreen	61	143	188	139	255
DarkSlateBlue	62	72	61	139	255
DarkSlateGray	63	47	79	79	255
DarkTurquoise	64	0	206	209	255
DarkViolet	65	148	0	211	255
DeepPink	66	255	20	147	255
DeepSkyBlue	67	0	191	255	255
DimGray	68	105	105	105	255
DodgerBlue	69	30	144	255	255
Firebrick	70	178	34	34	255
ForestGreen	72	34	139	34	255
Fuchsia	73	255	0	255	255
Gold	76	255	215	0	255
Goldenrod	77	218	165	32	255
Gray	78	128	128	128	255
Green	79	0	128	0	255
GreenYellow	80	173	255	47	255

Color	knownColor	R	G	B	A
HotPink	82	255	105	180	255
IndianRed	83	205	92	92	255
Indigo	84	75	0	130	255
Khaki	86	240	230	140	255
LawnGreen	89	124	252	0	255
LightBlue	91	173	216	230	255
LightCoral	92	240	128	128	255
LightGray	95	211	211	211	255
LightGreen	96	144	238	144	255
LightPink	97	255	182	193	255
LightSalmon	98	255	160	122	255
LightSeaGreen	99	32	178	170	255
LightSkyBlue	100	135	206	250	255
LightSlateGray	101	119	136	153	255
LightSteelBlue	102	176	196	222	255
Lime	104	0	255	0	255
LimeGreen	105	50	205	50	255
Magenta	107	255	0	255	255
Maroon	108	128	0	0	255
MediumAquamarine	109	102	205	170	255
MediumBlue	110	0	0	205	255
MediumOrchid	111	186	85	211	255
MediumPurple	112	147	112	219	255
MediumSeaGreen	113	60	179	113	255
MediumSlateBlue	114	123	104	238	255
MediumSpringGreen	115	0	250	154	255
MediumTurquoise	116	72	209	204	255
MediumVioletRed	117	199	21	133	255
MidnightBlue	118	25	25	112	255
Moccasin	121	255	228	181	255
NavajoWhite	122	255	222	173	255
Navy	123	0	0	128	255
Olive	125	128	128	0	255
OliveDrab	126	107	142	35	255
Orange	127	255	165	0	255
OrangeRed	128	255	69	0	255
Orchid	129	218	112	214	255
PaleGoldenrod	130	238	232	170	255
PaleGreen	131	152	251	152	255
PaleTurquoise	132	175	238	238	255
PaleVioletRed	133	219	112	147	255
PeachPuff	135	255	218	185	255
Peru	136	205	133	63	255
Pink	137	255	192	203	255
Plum	138	221	160	221	255
PowderBlue	139	176	224	230	255

Color	knownColor	R	G	B	A
Purple	140	128	0	128	255
Red	141	255	0	0	255
RosyBrown	142	188	143	143	255
RoyalBlue	143	65	105	225	255
SaddleBrown	144	139	69	19	255
Salmon	145	250	128	114	255
SandyBrown	146	244	164	96	255
SeaGreen	147	46	139	87	255
Sienna	149	160	82	45	255
Silver	150	192	192	192	255
SkyBlue	151	135	206	235	255
SlateBlue	152	106	90	205	255
SlateGray	153	112	128	144	255
SpringGreen	155	0	255	127	255
SteelBlue	156	70	130	180	255
Tan	157	210	180	140	255
Teal	158	0	128	128	255
Thistle	159	216	191	216	255
Tomato	160	255	99	71	255
Turquoise	161	64	224	208	255
Violet	162	238	130	238	255
White	164	255	255	255	255
Yellow	166	255	255	0	255
YellowGreen	167	154	205	50	255

Anhang D EULA

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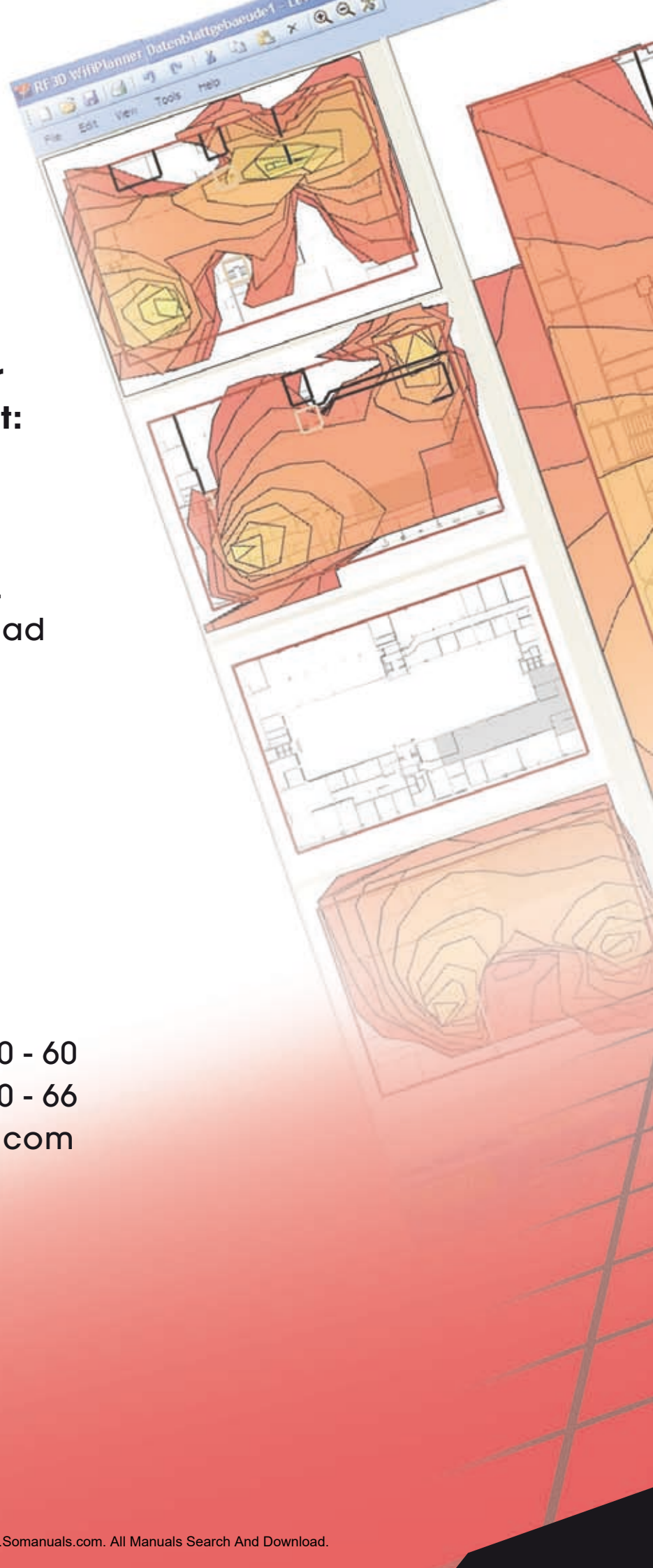
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