4 Distributed Antenna Systems The lesson learned from Section 3.5 is clear; you need to distribute a uniform dominant signal inside the building, from the indoor cell, using indoor antennas in order to provide sufficient	4 Hệ thống ăngten phân tán Từ Phần 3.5, chúng ta dễ dàng thấy rằng cần phải phân phối tín hiệu đồng đều bên trong toà nhà, từ trạm phát trong nhà dùng ăng ten trong nhà để phủ sóng toàn bộ khu vực và đảm bảo

coverage and dominance. In order to do so you must split the signal from the indoor base station (trạm cơ sở, trạm gốc) to several antennas throughout the inside of the building.	phân phối đồng đều. Để làm vậy, chúng ta phải tách tín hiệu từ trạm cơ sở trong nhà đến một số ăng ten nằm bên trong toà nhà.
Ideally these antenna points should operate roughly at the same power level, and have the same loss/noise figure on the uplink to the serving base station. The motivation for the uni-formly distributed coverage level for all antennas in the building is the fact that all the antennas will operate on the same cell, controlled by the same parameter setting. In practice passive DAS will often not provide a uniform design to all antennas; you might have one antenna with 10 dB loss from the base station, and in the same cell an antenna with 45 dB loss back to the base station, and the actual parameter setting for handover control etc. on the base station might not be able to cater for both scenarios. Therefore uniform performance throughout the distributed antenna system is a key parameter in order to optimize the performance of the indoor coverage system.	Lý tưởng nhất là các điểm đặt ăng ten nên hoạt động ở gần cùng một mức công suất, và có cùng chỉ số tổn hao/nhiễu trên liên kết lên đến trạm cơ sở phục vụ. Để mức độ bao phủ phân tán đồng đều cho tất cả các ăng ten trong toà nhà thì tất cả các ăng ten sẽ họat động trên cùng một cell (tầng, phòng nhỏ), được điều khiển bởi cùng một tham số. Trong thực tế, DAS thụ động thường không cung cấp thiết kế đồng đều cho tất cả các ăng ten; có thể bạn chỉ có một ăng ten với độ tổn hao 10 dB từ trạm cở sở, và trong cùng một cell ăng ten với độ tổn hao 45 dB quay lại cùng một trạm cơ sở, và thiết lập tham số thực sự để điều khiển chuyển giao trên trạm cơ sở không thể phục vụ cho cả hai trường hợp. Do đó, hiệu suất đồng đều trên toàn bộ hệ ăng ten phân tán là một tham số then chốt để tối ưu hoá hiệu suất của hệ phủ sóng trong nhà. Pico cell: tham khảo link bên dưới http://www.rfd.gov.vn/tintuc/Pages/the-gioi-vo-tuyen.aspx?ItemID=628
There are many different approaches to how you can design an indoor coverage system with uniformly distributed coverage level; passive distribution, active distribution, hybrid solutions, repeaters or even distributed Pico cells (Small Cells) in the building. Each of these approaches have their pros and cons, all	Có nhiều phương pháp khác nhau để thiết kế hệ phủ sóng trong nhà với mức bao phủ phân phối đồng đều; phân bố thụ động, phân bố chủ động, các giải pháp lai hoá, các bộ lặp hoặc thậm chí các Pico cell phân tán (các cell nhỏ) trong toà nhà. Mỗi phương pháp này đều có ưu và nhược điểm riêng, tuỳ thuộc vào từng dự án đang thực thi.

depending on the project at hand. One design approach could be perfect for one project, but a very bad choice for the next project - it all depends on the building, and the design requirements for the current project, and the future needs in the building.	Một phương pháp thiết kế có thể hoàn hảo cho một dự án nhưng có thể là lựa chọn không tốt cho dự án kế tiếp-tất cả tuỳ thuộc toà nhà, và các yêu cầu thiết kế của dự án hiện tại, và các nhu cầu tương lai trong toà nhà.
Seen purely from a radio planning perceptive you should ideally select the system that can give the most downlink power at the antenna points and the least noise load and loss on the uplink of the base station, and at the same time provide uniform coverage and good isolation to the macro network. On top of the radio planning requirement, other parameters like installation time and costs, surveillance and upgradeability play a significant role. In practice the service requirements and the link budget (see Section 8.1.3) will dictate how much loss and noise you can afford and still accommodate the service level inside the building you aredesigning for.	[redacted]
Passive or Active DAS	
Traditionally passive distributed antenna systems have been used extensively for 2G in the past many years. Therefore naturally many radio planners will see this as the first choice when designing indoor coverage for 3G/4G systems. However, it is a fact that, for 3G and especially for 4G active distributed antenna systems will often give the best radio link performance and higher data rates. The main degrading effect from the passive systems is the high	[redacted]

losses, degrading the power level at the antenna points and increasing the base station noise figure on the higher frequencies used for 3G/4G. 3G and 4G can perform really high-speed data transmission, but only if the radio link quality is sufficient, and passive systems will to a large extent compromise the performance; see Section 7.2 for more details on NF increase due to passive loss.	[redacted]
Another big concern with passive distributed antenna systems is the lack of supervision. If a cable is disconnected the base station will not generate any voltage standing wave radio (VSWR) alarm, due to the high return loss through the passive distributed antenna system. Distributed indoor antenna systems are implemented in the most important buildings, serving the most important users, generating revenue in our network. Surely you would prefer to have surveillance of any problems in the DAS system.	[redacted]
On the other hand, passive systems are relatively easy to design; and components and cables are rigid and solid, if installed correctly. Passive distribution systems can be installed in really harsh environments, damp and dusty production facilities, tunnels, etc., places where active components will easily fail if not shielded from the harsh environment. Passive	[redacted]

distribution systems can be designed so they perform at high data rates, even for indoor 4G solutions - but only for relative small buildings, projects where you can design the passive distributions system with a low loss, short distances of c

4.1.2 Learn to Use all the Indoor Tools

It is important that the radio designer knows the basics of all the various types of indoor coverage distribution solutions. In many projects the best solution will be a combination of the various types of distribution hardware. Good indoor radio planning is all about having a well- equipped toolbox; if you have more tools in your toolbox, it is easier to do the optimum design for the indoor solution. Having only a hammer might solve many problems, but only having a hammer in you toolkit will limit your possibilities. If you only know about passive distribution, learn about the possibilities and limitations of active distribution, repeaters and Pico cells. This will help you design high-performing indoor coverage distribution systems that are future-proof and can make a solid business case. After all that’s why you are here - to generate revenue in the network.

Indoor radio planning is not about using one approach only. Learn the pros and cons of all the various ways of designing indoor coverage, and then you will know what is the best approach for the design at hand. Often

[redacted]

the best approach will be a combination of the different solution types.

Passive Components

Before you start exploring the design of passive distributed antenna systems, you need to have a good understanding of the function and usage of the most common type of passive components used when designing indoor passive distributed antenna systems.

4.2.1 General

Inside buildings you must fulfill the internal guidelines and codex that apply for the specific building. In general you will be required to use fire-retardant CFC-free cables and components.

Be very aware of how to minimize any PIM (passive intermodulation) problems. Also be sure that the components used fulfill the required specification, especially when designing high-power passive distributed antenna systems. The effect of combining many high-power carriers on the same passive distributed antenna system using high-power base stations will produce a high-power density in the splitters and components close to the base stations. Use only quality passive components that can meet the PIM and power requirements, 150 dBc or better specified components (see Section 5.7.4).

.2 Coax Cable

Obviously coax cable is widely used

[redacted]

[redacted]

[redacted]

[redacted]

in all types of distributed antenna systems, especially in passive systems. Therefore it is important to get the basis right with regards to cable types, and losses. Table 4.1 shows the typical losses for the commonly used types of passive coaxial cables. For accurate data refer to the specific datasheet for the specific cable from the supplier you use. Often there will be a distance marker printed on the cable every 50 cm or 1 m, making it easy to check the installed cable distances.	[redacted]
Calculating the Distance Loss of the Passive Cable It is very easy to calculate the total loss of the passive coaxial cable at a given frequency. Example Calculating the total longitudinal loss of 67 m of 1 inch coax on 1800 MHz, according to Table 4.1: 2 total loss = distance (m)x attenuation per meter total loss = 67m x 0.1dB / m = 6.7dB	[redacted]
The main expense implementing passive indoor systems is not the cable cost, but rather the price for installing the cable. Installing heavy rigid passive cable can be a major challenge in a building. In particular, the heavier types of cable from size - inch and up are a major challenge. These heavy cables literally take whole teams of installers; after all the cable is heavy, and a challenge to install without dividing the cable into shorter sections.	[redacted]

Carefully consider the price of installing the cable against the performance. You might be alright with 2 dB extra cable loss, if you can save 50% of the installation costs by just selecting a cable size thinner. On the other hand, do be sure that the distribution system will be able to accommodate the higher frequencies and data speeds on 3G and HSPA—"

4.2.3 Splitters

Splitters and power dividers are the most commonly used passive components in distributed antenna systems, dividing the signal to or from more antennas. Splitters (as shown in Figure 4.1) are used for splitting one coax line into two or more lines, and vice versa. When splitting the signal, the power is divided among the ports. If splitting to two ports, only halfpower minus the insertion loss, typically about 0.1 dB, is available at the two ports. It is very

Table 4.1 Typical attenuation of coaxial cable

Figure 4.3 Taps, adjustable and fixed

important to terminate all ports on the splitter; do not leave one port open. If it is unused, terminate it with a dummy load.

Example

You can calculate the loss through the splitter:

splitter loss = 10 log (no. of ports) + insertion loss For a 1:3 splitter (as shown in Figure 4.2), the attenuation

[redacted]

[redacted]

[redacted]

[redacted]

will be: 10log(3) + 0.1dB = 4.87dB In this example, when we feed a 1:3 splitter 10 dBm power on port 1, the output power on ports 2-4 will be 10-4.87 = 5.13 dBm 4.2.4 Taps/Uneven Splitters Tap splitters (as shown in Figure 4.3) are used like splitters, used to divide the signal/power from one into two lines. The difference from the standard 1:2 splitter is that the power is not equally divided among the ports. This is very useful for designs where you install one heavy main cable through the building, and then 'tap' small portions of the power to antennas along the main cable. By doing so, you reduce the need to install many parallel heavy cables, and still keep the loss low. This is an application that is commonly used in high-rise buildings, where you install a heavy 'vertical' cable and tap off power to the individual floors (as shown in Figure 4.14). By adjusting the coupling loss on the different tappers by selecting the appropriate value, you can actually balance out the loss to all the floors in the high-rise building, providing the required uniform coverage level. Table 4.2 Typical taps and their coupling losses\ Figure 4.4 Typical configurations of tappers on a distributed antenna system to keep a uniform coverage	[redacted]

level for all antennas over a large distance	[redacted]
Figure 4.5 RF attenuator Taps come in various types, the principle being that there is a low-loss port (1-2) and then a higher-loss port (3), where you ‘tap’ power of to a local antenna/cluster of antennas. In a high-rise building, you install one vertical heavy - or 1- inch cable in the vertical cable riser, and then use tappers on each floor to feed a splitter that divides out to two to four antennas fed with 1 inch coax. Standard tappers are available with the values shown in Table 4.2.	[redacted]
Example of Use In this example (as shown in Figure 4.4), we can see that, even over long distances (200 m at 7 2G-1800), using a - inch main cable, and different types of tappers and a splitter, we can keep a relative constant attenuation of all of the antennas within a variation of 1.5 dB, even though the longitudinal loss of the main cable varies up to 12 dB. It is evident that it is possible to balance out the loss efficiently when using tappers.	[redacted]
Attenuators Attenuators (as shown in Figure 4.5), attenuate the signal with the value of the attenuator. For example a 10 dB attenuator will attenuate the signal by 10 dB (port 2 = port 1 - attenuation).	[redacted]

Attenuators are used to bring higher power signals down to a desired range of operation, typical to avoid overdriving an amplifier, or to limit the impact of noise power from an active distributed antenna system (see Section 10.2).	[redacted]
Typical standard attenuator values are 1, 2, 3, 6 10, 12, 18, 20, 30 and 40 dB. When you combine them, you can get the desired value; variable attenuators are also available, but typical only for low power signals. Note that, when attenuating high power signals for many carriers, typically for multioperator applications you should use a special type of attenuator, a ‘cable absorber’, to avoid PIM problems.	[redacted]
.6 Dummy Loads or Terminators Terminators (as shown in Figure 4.6), are used as matching loads on the transmission lines, often on one port of a circulator, or any ‘open’ or unused ports on other components. In applications that are sensitive for PIM, the better option is to use a cable absorber (-160 dBc) 4.2.7 Circulators The circulator splitter (as shown in Figure 4.7) is a nonreciprocal component with low inser-tion loss in the forward direction (ports 1-2, 2-3 and 3-1) and high insertion loss in the	[redacted]

reverse direction (ports 2-1, 3-2 and 1-3). The insertion loss in the forward direction is typically less than 0.5 dB and in the reverse direction better than 23 dB. You can get ‘double stage’ isolators with reverse isolation better than 40 dB if needed.	[redacted]
Figure 4.6 Standard 50 Q dummy load or terminator mples of Use The circulator can be used to protect the port of a transmitter (as shown in Figure 4.8) against reverse power from reflections caused by a disconnected antenna or cable in the antenna system.	[redacted]
A common application for circulators in mobile systems is to use the circulator to separate the transmit and receive directions from a combined Tx/Rx port (as shown in Figure 4.9). This is mostly used for relatively low power applications due to PIM issues in the circulator. For high-power applications it is recommended to use a cavity duplex filter to separate the two signals.	[redacted]
Circulators can also be used to isolate transmitters in a combined network for a multioperator system (as shown in Figure 5.28). 4.2.8 A 3dB Coupler (90° Hybrid) The 3 dB coupler shown in Figure 4.10 are mostly used for combining signals from two signal sources. At the same time the coupler will split the	[redacted]

two combined signals into two output ports. This can be very useful when designing passive distributed antenna systems.	[redacted]
Figure 4.9 Circulator used as a duplexer, separating Rx and Tx from a combined Rx/Tx line	[redacted]
The 3 dB coupler has four ports; two sets of these are isolated from each other (ports 2 and 3/1 and 4). If power is fed to port 1, this power is distributed to ports 2 and 3 (-3 dB). Port 4 will be powerless provided that ports 2 and 3 are ideally matched. Normally a terminator will be connected to port 4.	[redacted]
Example of Use If you need to combine two transmitters or two transceivers (TRXs/TRUs), you can use a 3 dB coupler (as shown in Figure 4.11). However, if you need to combine the two transmitters and at the same time distribute the power to a passive distributed antenna system with several antennas, you should connect one part of the DAS to port 2 and the other to port 3 (as shown in Figure 4.12). Thus you will increase the power on the DAS by a factor of 2 (3 dB). This method is to be preferred, and will increase the signal level by 3 dB in the building, rather than burning the 3 dB in the dummy load on port 3 (as shown in Figure 4.11) - this will only generate heat!	[redacted]
Figure 4.12 Combining two TRX and splitting out to a distributed antenna syst	[redacted]

One parameter that is very important to keep in mind when designing with passive compo-nents is not exceed the maximum power rating that the passive component can handle. This is a particular problem for high capacity or multioperator passive DAS solutions, where you combine many carriers and base stations at high power levels into the same passive distribution system.	[redacted]
Calculating the Total Power from the Base Stations How do we calculate the total power? Example, Calculating Composite Power on a Passive DAS We have a multioperator system in an airport; there are three 2G operators connected at the same point, and each operator has six TRX. The base stations output 46 dBm into the distributed antenna system. In total we have 3x6 = 18TRX Worst case is that all carriers are loaded 100%; therefore each 2G radio transceiver transmits a full 46 dBm constantly on all time slots. We need to sum all the power, but first we have to convert from dBm to Watt: dBm P(mW) = 10^ =40000(mW)+ = 40 W	[redacted]
We have 18 carriers of 40 W each; the total composite power is:	[redacted]
Total power = 18x40 W = 720W Then back to dBm = 10 -1 log (720 000 [mW]) = 58.6 dBm.	[redacted]

Therefore we need to insure that the passive components can handle 720 [Watt]/58.6 dBm constantly in order to make sure the system is stable. The PIM Power PIM is covered in Section 5.7.4. However, let us calculate the level of the PIM signals. If we take a passive component, with a PIM specification of -120 dBc, the maximum PIM product will be 120 dB below the highest carrier power. For example, continued from the previous example, we can expect the worst case PIM product to have a signal level of 46dBm-120dB = -74 dBm.	[redacted]
This is a major concern; -74 dBm in unwanted signal, especially if the inter-modulation product falls in the UL band of one of the systems, it will become a very big problem that will degrade the performance of that system/channel.	[redacted]
Exceeding the maximum the maximum power rating on a passive component will make it even worse. Be sure to use passive components with very good specifications when designing high-power, high-capacity solutions, and be absolutely sure to keep within the power specifications of all the components. Duplexer Figure 4.13 The typical filters used to separate frequency bands: diplexer and triplexer. Also, the duplexer used to separate uplink and downlink Filters When designing indoor solutions there are basically two types of filters that	[redacted]

you will encounter, the duplexer and the diplexer or triplexer, as shown in Figure 4.13. Duplexer The duplexer is used to separate a combined TX/RX signal into separate TX and RX lines. Bear in mind the isolation between the bands as well as the insertion loss and the PIM specifications.	[redacted]
Diplexer/Triplexer The diplexer will separate or combine whole bands from or with each other, for example, input combined 2100 and 1800 MHz and output separate 2100 and 1800 MHz bands. Bear in mind the isolation between the bands as well as the insertion loss and the PIM specifications.	[redacted]
A three band version that can separate or combine 900, 1800 and 2100 MHz is also avail-able, called a triplexer. Some manufacturers even do combined components that contain both a diplexer or triplexer and a dupl 4.3 The Passive DAS	[redacted]
Now that we know the function of all the passive components, we are able to make a design of a passive distributed antenna system. Passive DAS systems are the most used approach when providing indoor solutions, especially to small buildings. \the Passive DAS The passive DAS is relatively easy to plan; the main thing you need to do is to calculate the maximum loss to each antenna in the system, and do the link	[redacted]

budget accordingly for the particular areas that each antenna covers. You will need to adapt the design of the passive DAS to the limitations of the building with regards to restrictions to where and how the heavy coax can be installed. Often the RF planner will make a draft design based on floor plans before the initial site survey, and afterwards adapt this design to meet the installation requirements of the building. In fact, the role of the RF planner is often limited to installation planning, not RF planning, when designing passive DAS.

[redacted]

Figure 4.14 Typical passive DAS diagram with the basic information and data

[redacted]

It is very important that you know all the cable distances and types so that you can calculate the loss from the base station to each individual antenna. Therefore you must do a detailed site survey of the building, making sure that there are cable routes to all of the planned antennas. When doing passive DAS design, you will often be limited and restricted as to where you can install the rigid passive cables. Frequently, the limitations of installation possibilities will dictate the actual passive DAS design, and because of this the final passive solution will often be a compromise between radio performance and the reality of the installation restrictions. You need the exact loss of each coax section in the system, in order to verify the link budget (see Chapter 8),

[redacted]

and place the antennas. A typical passive DAS design can be seen in Figure 4.14, showing a small office building. This design relies on a main vertical - inch cable, using tappers on each floor that tap off power to the horizontal via - inch coax cables to 1:3 splitters on each floor.	[redacted]
The advantage is that the heavy 7 8 inch cable can be installed in the vertical cable raiser where there is easy access and the installation of the rigid coax will be relative simple. On the office floors it is more of a challenge to installing coaxial cable as no cable trays are available.	[redacted]
By using 'thin' 1 2 inch coax for these horizontal cable runs, we can simply strap the cable onto the frame of the suspended ceiling with cable ties, making the installation relatively fast and inexpensive.	[redacted]
The coverage in this example is to some extent uniform; there is acceptable balance bet-ween the antennas serving the three office floors. It was decided to radiate more power into the top of the three elevator shafts, in order to penetrate the lift-car, and provide sufficient coverage inside the lift for voice service. When doing the diagram (Figure 4.14), all information must be documented, including losses of components and cables, type numbers, component numbers and total loss to each antenna. This design	[redacted]

documentation must contain all relevant information, and must be available on-site in case of trouble-shooting. Trouble-shooting is an issue with passive systems. You will need to use a power meter connected to selected points throughout the passive DAS in order to disclose any faults, in case of a fault on the system. You could use the ‘one meter test’ from Section 5.2.9 for the worst faults, but you need to connect a power meter to the DAS to be absolutely sure of the power level. This is the main downside of using passive DAS: trouble-shooting is painstaking. Also, even realizing that there is a fault in the system is pretty much a question of customer complaints from the building; even severe faults on the passive DAS will give no alarm at the base station. Main Points About Passive DAS There are many arguments for and against the use of passive DAS. Remember that passive DAS is just one of the tools in the indoor radio planning toolkit, sometimes passive DAS will be the best choice, sometimes not. The clever indoor radio planner will know when to use this approach, and when not to. The advantages of passive DAS are: • It is straightforward but time-consuming to design. • Components from different manufacturers are compatible. • It can be installed in harsh environment.	[redacted] [redacted] [redacted]

The disadvantages of passive DAS are:	[redacted]
• There is no surveillance of errors in the system - the base station will not give VSWR alarm even with errors close to the base station due to high return loss.	[redacted]
• It is not flexible for upgrades (split into more sectors, higher frequencies).	[redacted]
• High losses will degrade data performance.	[redacted]
• It is hard to balance out the link budget for all antennas, and to get a uniform coverage level.	[redacted]
• It requires a high-power base station and dedicated equipment room for site support equipment, power supply, etc.	[redacted]
The fact remains that passive DAS is the most implemented type of DAS on a global basis. However the need for 3G and 4G service and even higher speed data service in the future will affect the preference for selecting DAS types.	[redacted]
The attenuation of the passive DAS is the main issue in this context: frequencies used for future mobile services will most likely get higher and higher, and the modulation schemes applied for high-speed data services are very sensitive to the impact of the passive cable loss. This will degrade the downlink power at the antenna, and on the uplink the high noise figure of the system caused by the passive losses will limit the uplink	[redacted]

data speeds. Surely passive systems will continue to be used in the future, but only for small buildings with a few antennas, and the losses must be kept to a minimum.

Applications for Passive DAS

Passive DAS is the most widely used distribution system for indoor coverage systems for mo-bile service. Passive DAS can be used for very small buildings with a low-power base station and a few antennas, all the way up in size to large airports, campuses, etc.

The main challenge in using passive DAS is the installation of the rigid cables, which have a high impact on the installation cost, and might limit the possibilities as to where antennas can be installed. This could be an issue in solving the high-rise problem covered in Section 3.5.3. The building will more or less dictate the design, because of the installation challenge.

Degraded data service can be an issue if the attenuation of the system gets too high, espe-cially on 3G/4G. This problem can be solved by dividing the passive DAS into small sections or sectors, each serviced by a local base station. However, this is costly and often ineffective use of the capacity resources; refer to Section 6.1.9 regarding trunking gains. The extra back-haul costs, interface loads on the core network and software licenses to the equipment supplier also add to the cost of distributing the base stations.

[redacted]

[redacted]

[redacted]

High user RF exposure with passive DAS. Mobiles inside the building will radiate on relatively high power, due to the fact that the mobile has to overcome the passive losses by transmitting at a higher power level (see Section 4.13). Thus the mobile will expose the users to higher levels of electromagnetic radiation. Maintenance and trouble-shooting are challenging in passive DAS systems. Be sure to use a certified installer, and do not underestimate the importance of proper installation code and discipline when installing coax solutions and connectors. 'Passive systems never fail' - this is not true. Most likely, you just do not know that there is a fault! Trust me, when an installer is on top of a ladder at four o'clock in the morning, mounting the 65th coax connector that night, he might be a little sloppy. Even small installation faults can result in severe problems, inter-modulation issues, etc. Do not underestimate the composite power in a passive system when combining many carriers and services into the Active DAS The principle function of an active distributed antenna system is that, like a passive distributed antenna system, it distributes the signal to a number of indoor antennas. However, there are some big differences. The active distributed antenna system normally relies on thin cabling,	[redacted]

tributed Antenna Systems

optical fibers and IT type cables, making the installation work very easy compared with the rigid cables used for passive systems.

The active distributed antenna system consists of several components, the exact configuration depending on the specific manufacturer. All active distributed antenna systems will to some extent be able to compensate for the distance and attenuation of the cables.

The ability to compensate for the losses of the cables interconnecting the units in an active distributed antenna system makes the system very easy and fast to plan, and easy to implement in the building.

Whereas, when designing a passive distributed antenna system, you need to know the exact cable route and distance for each cable in order to calculate the loss and link budget, when designing active distributed antenna systems it does not matter if the antenna is located 20 m from the base station or even 5 km. The performance will be the same for all antennas in the system; the active DAS system is transparent. This ‘transparency’ is obtained automatically because the active system will compensate for all cable losses by the use of internal calibrating signals and amplifiers. This is typically done automatically when you connect the units and commission the system. Therefore the radio planner will not need to perform a

[redacted]

[redacted]

[redacted]

detailed site survey. It does not matter where the cables are installed, and the system will calibrate any imbalance of the cables. Nor does the radio planner need to do link budget calculations for all the antennas in the building; all antennas will have the same noise figure and the same downlink power, giving truly uniform coverage throughout the building. These active DAS systems are very fast and easy to plan, implement and optimize.

It is a fact that modern buildings are very dynamic in terms of their usage. Having a distributed antenna system that can easily be upgraded and adapted to the need of the building is important. It is important for the users of the building, the building owner and the mobile operator. The active DAS can accommodate that concern, being easy and flexible to adapt and to upgrade. There is no need to rework the whole design and installation if there are changes and additions in the system; there is always the same antenna power, whatever the number of or distance to the antennas.

Pure Active DAS for Large Buildings

Ideally in an active DAS there will be no passive components that are not compensated by the system. Therefore the active DAS is able to monitor the end-to-end performance of the total DAS and give alarms in case of malfunction or disconnection of cables and antennas. These active DAS systems can support one band-one operator, or large multioperator

[redacted]

[redacted]

[redacted]

solutions. The philosophy behind the purely active DAS architecture is to have the last DL amplifier and the first UL amplifier as close to the antenna as possible. Co-located with the antenna is the remote unit (RU), avoiding any unnecessary degrading losses of passive coax cables.	[redacted]
When using this philosophy, having the RU located close to the antenna, there is no need to use excessive downlink transmit power from the base station to compensate for losses in passive coax cables; therefore the system can be based on low to medium transmission power from the RU, because all the RU downlink power will be delivered to the antenna with no losses.	[redacted]
Data Performance on the Uplink Purely active DAS has big advantages for the uplink data performance. Having the first uplink in the RU, with no losses back to the base station, will boost the data performance. This is very important for the performance of high-speed data, the higher EDGE coding schemes on 2G, high-speed data on 3G and in particular, 4G performance.	[redacted]
The main difference between the passive and active DAS on the uplink performance is that, even though the active DAS will have a certain noise figure, it will be far lower compared with the high system noise figure on high-loss passive DAS systems. The	[redacted]

effective NF performance is basic radio design; refer to Chapter 7 for more details on how the loss and noise figure affect the system performance. Some full active DAS claims wide band support, we need to consider the risk on the UL when unwanted (not serviced by the DAS) signals, “hits” with high level on the UL. By the use of transmission via low-loss optical fibers, a typical active DAS can reach distances of more than 5 km. The cable between EU and RU up to 250 m makes these types of solutions applicable in medium to large buildings, typically large office buildings, shopping malls, hospitals, campus environments and tunnels.	[redacted]
The active DAS will typically only require about +10 dBm input power from the base station; there is no need for a large, high-power base station installation, with heavy power supply, air- conditioning, etc. A mini-base station can be used to feed the system, and the system components are so small that an equipment room can be avoided; everything can simply be installed in a shaft. Less power consumption due to the need for less power from the base station with no ventilation saves on operational costs, and makes the system more green and more CO_2 friendly. The fact that the installation work uses the thin cabling infrastructure of an active DAS can also cut project cost and implementation time.	[redacted] [redacted]

Time to deployment is also short compared with the traditional passive design. You are able to react faster to the users' need for indoor coverage, and thus revenue will be generated faster, and the users will be more loyal.	[redacted]
In order to understand how you can use active DAS for indoor coverage planning, you need to understand the elements of the active DAS. Some active DAS systems use pure analog signals; other systems convert the RF to digital and might also apply IP transmission internally.	[redacted]
The names of the units, numbers of ports, distances and cable types will be slightly differ-ent, but the principle is the same (Figure 4.15). Typically these types of DAS systems will be able to support both 2G and 3G/4G, so you will need only one DAS system in the building to cater for all mobile services and operators.	[redacted]
Up to 400 m Thin IT cables The main unit (MU) connects to the low-power base station or repeater; the MU distributes the signals to the rest of the system via expansion units (EU). The MU will typically be connected to the EU by optical fibers. The MU is the 'brain' of the system and also generates and controls internal calibration signals in the system together with internal amplifiers, and converters adjust gains	[redacted]

and levels to the different ports in order to compensate for the variance of internal cable loss between all the units.	[redacted]
The MU will also monitor the performance of the DAS system, communicating data to all units in the DAS. In the event of a malfunction or a warning it is able to send an alarm signal to the base station that enables the operator to exactly pinpoint the root of the problem and resolve the problem fast.	[redacted]
Detail about specific alarms is typically good; the system will normally pinpoint the exact cable, antenna or component that is the root of the problem. Thus the downtime of the DAS can be limited, and the performance of the system re-established quickly.	[redacted]
It is possible to see the status of the whole system and the individual units at the MU, using LEDs, an internal LCD display or via a connected PC - it all depends on the manufacture of the system.	[redacted]
It is also possible to access the MU remotely via modem or via the internet using IP, per-form status investigation, reconfiguration and retrieve alarms in order to ease trouble-shooting and support.	[redacted]
The EUs are typically distributed throughout the building or campus and are placed in central cable raisers or IT X-connect rooms. The EU is connected to the MU using optical	[redacted]

fibers, typically separate fibers for the UL and the DL. The EU converts the optical signal from the MU to an electrical signal and distributes this to the RU. Ideally the EU will also feed the DC power supply to the RUs via the existing signal cable in order to avoid the need for local power supply at each antenna point (RU). In many cases LEDs will provide a status of the local EU and subsystem (the RUs). Some systems can use both single mode fiber (SMF) and multimode fiber (MMF), and some systems only SMF. It is important to consider this when planning to reuse already installed fiber in the building, since old fiber installations are typically only MMF. Installation of fibers and fiber connectors takes both education and discipline, so be sure that your installer has been certified for this work, and always refer to the installation guidelines from the manufacturer of the DAS. Remote Unit The RU is installed close to the antenna, to keep the passive losses to a minimum and improve the radio link performance. The RU converts the signal from the EU back to normal DL radio signals and the radio signal from the mobiles on the UL is converted and transmitted back to the EU. The RU is located close to the antenna, typically only connected to a short RF jumper. This will insure the best RF	[redacted] [redacted] [redacted]

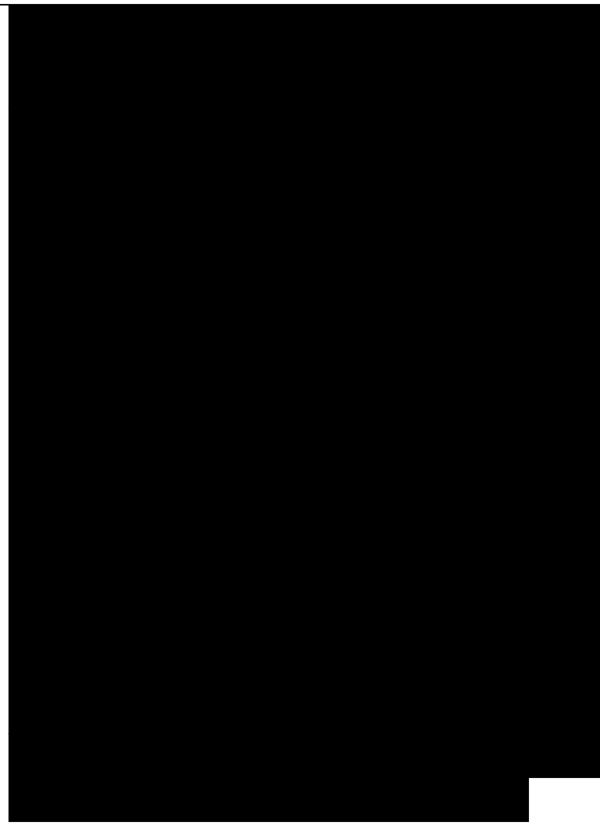
performance and the possibility of active DAS to detect when the antenna is disconnected from the system.	[redacted]
The RU should be DC fed with power from the EU in order to avoid expensive local power supply at each antenna point. In addition, the RU should be designed with no fans or other noisy internal parts, in order to enable the system to be installed in quiet office environments.	[redacted]
Figure 4.16 Example of a pure active DAS for small buildings; up to 400 m distance between the base station and the antennas with no loss The RU is connected to the EU with a thin coax, or CAT5 cables or similar ‘thin cabling’, making it very easy and quick to install compared with the rigid passive coax cables used for passive DAS. „A.4.3 Pure Active DAS for Small to Medium-size Buildings Even though that active DAS is normally considered applicable for large buildings, small buildings can be designed with pure active DAS (Figure 4.16), thereby utilizing the benefits of having a high-performance DAS, with light cabling infrastructure, a small low-power base station and full surveillance of the DAS Main Unit The system consists of one MU connected directly to RUs with thin coax, CAT5 or other ‘IT-type’ cables; there is no use of optical fibers. This small system has all the same functions and advantages with regards	[redacted]

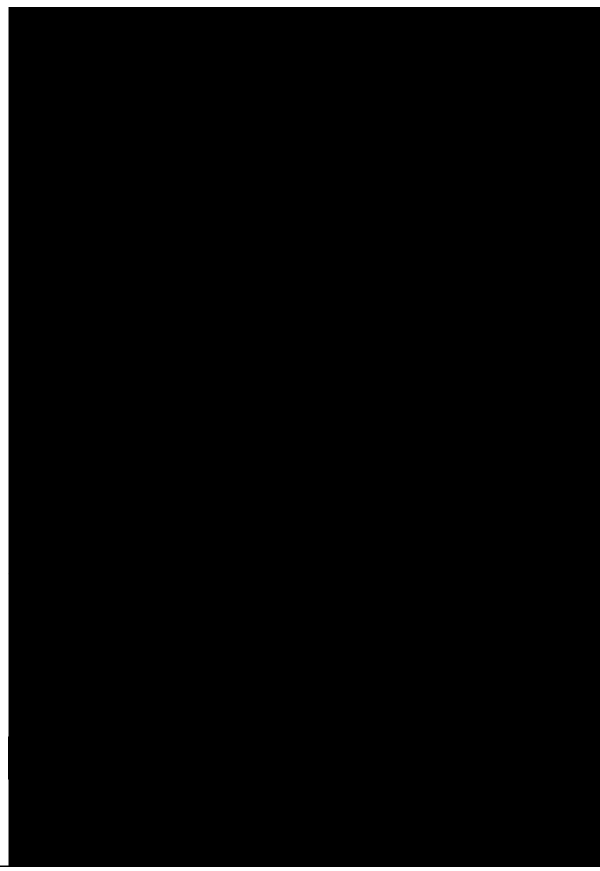
to auto calibration, uniform performance and improved radio link as the large systems. Even the detailed alarming is the same; full monitoring of the system, including the antennas, is possible.	[redacted]
For medium-sized buildings, you can feed more of these systems in parallel to obtain more antenna points. This makes this medium system a very cost-effective and high-performing system.	[redacted]
Both of these pure active systems are very cost-effective and easy to install. Often the IT team of the specific building can carry out the installation for the operator, thus sharing the cost load with the operator. In this way the building owner or user pays for the installation and the	[redacted]
The large version of the pure active DAS as shown in Figure 4.15 is a very versatile tool for large buildings or campuses. The low-impact installation of the pure active DAS, using and reusing thin 'IT-type' cabling, makes this solution ideal in corporate buildings, hotels and hospitals. The installation is fast and easy, making it possible to react to requests for indoor coverage swiftly. The concept of having the RU close to the antenna boosts the data performance in these high-profile buildings, where 3G/HSPA service is a must.	[redacted]

Radiation from mobiles and DAS antenna systems are a concern for the users of the building. The pure active DAS has the RUs installed close to the antenna; this boosts the uplink data performance. In addition there is a side effect: because the system calibrates the cable losses, there is no attenuation of the signal from the antenna to the base station. Hence the mobile can operate using very low transmit power, because it does not have to compensate for any passive cable loss back to the base station in order to reach the uplink target level used for power control. This makes this approach ideal for installations in hospitals, for example. See Section 4.13 for more details on electromagnetic radiation.

The small version of the pure active DAS shown in Figure 4.16 has all the advantages of the large system, but it does not rely on fiber installation. This takes some of the complexity out of the installation process. The system is ideal and cost-effective for small to medium-size buildings. Given that the system can reach more than 200 m from the MU to the RU, if installed in the center of a high-rise tower it could cover a 300 m-high building without any need for fiber (reserving some distance for horizontal cables). The systems are fully supervised all the way to the antenna; there is full visibility of the performance of the DAS.

Reliability is a concern, due to the number of units distributed throughout





the building. You must select a supplier that can document good reliability and mean time between failures (MTBF) statistics since access to so many active elements in the building can be a concern, when servicing the DAS. You also need to make sure that the location of all the installed units is documented, so they can be accessed for maintenance. You must be careful when installing these types of systems in moist, damp, dusty environments and shield them accordingly. 4.4.4 Active Fiber DAS 5 h 12 The increasing need for more and more bandwidth over the DAS to support multiple radio services, 2G, 2G, 3G, 4G, Wi-Fi, Tetra, PMR etc. has motivated a need for the indoor fiber DAS system to support a wider bandwidth to accommodate all the radio service, as shown in Figure 4.17. tributed Antenna Systems Up to 6km Optical fiber Master unit Figure 4.17 Optically distributed DAS for multiservice solutions Although it is debatable if it is feasible to combine many radio services with quite different design requirement into the same DAS, it is a fact that it is an installation advantage to have only one system and one set of antennas. The compromise will often be the performance on one or more of the services, and a costly DAS. If all services require 'full' indoor coverage, the consequence is that you	[redacted]

will have to design according to the lowest dominator. For example, if the DAS design turns out to show a coverage radius for 2G = 24m, 3G = 21m, but 4G = 10m, you have to place the antennas according to the 4G requirement, thus overdesigning the 2G and 3G system. In fact you often have to adjust the gain of the various services accordingly, to prevent signal leak from the building.	[redacted]
Another concern is the sector plan. Be sure that the DAS allows you to granulate all the different radio systems into independent sector plans, it is very likely you dont need the same sector lay-out for all the services.	[redacted]
The MU interfaces the fiber DAS to the different base stations. The MU distributes the signals directly to the optical remote units by the use of optical fibers. In many cases this fiber is a composite cable, containing both the fiber and the copper cable for power supply to the remote unit. Alternatively the power is fed locally at the optical remote unit.	[redacted]
The MU is the ‘brain’ of the system and also generates and controls internal calibration signals in the system together with internal amplifiers, and converters adjust gains and levels to the different ports in order to compensate for the variance of internal optical cable loss between	[redacted] bộ chuyển đổi điều chỉnh độ lợi và mức sang [redacted]

the MU and remote units.

The MU will also monitor the performance of the DAS system. In the event of a malfunc-tion or a warning, it must be able to send an alarm signal to the base station, which enables the operators to exactly pinpoint the root of the problem and resolve the problem fast. Details about specific alarms is typically good; the system will normally pinpoint the exact cable, antenna or component that is the root of the problem, thus the downtime of the DAS can be limited, and the performance of the system quickly re-established.

It is possible to see the status of the whole system and the individual units at the MU using LEDs, an internal LCD display or via a connected PC - it all depends of the manufacture of the system. It is also possible to access the MU remotely via a modem or the internet using IP, and perform status investigation or reconfiguration.

The ORU is installed throughout the building; it converts the optical signal from the MU back to normal RF and the RF UL signal from the mobiles is converted and transmitted to the MU. The ORU will typically need to operate on medium to high-output RF power and will often have two or more antenna connections, for the DAS antennas.

A variant of the optical DAS system can be seen in Figure 4.27, where the optically remote units can be daisy-chained, thereby avoiding the star configuration of Figure 4.17, where all

[redacted]

[redacted]

optical remote units need an individual fiber or set of fibers back to MU. This makes the optical system very applicable in tunnels, street DAS and high-rise buildings.	[redacted]
The downside with the daisy-chained system is that, if the fiber is cut, or the optical by-pass in one optical remote fails, then the rest of the DAS on the chain will be out of service.	[redacted]
This system is ideal for systems where there is a need for multiple services, other than 'just' 2G and 3G/4G. However, combining all these radio services into the same DAS is a challenge when it comes to inter-modulation and composite power resources.	[redacted] vì sẽ dẫn đến [redacted]
Power supply to the ORU can also be a challenge; when using the composite cable that has both the copper cable for the DC power and the fiber cable, you need to be careful about galvanic isolation between the buildings and grounding. The concept of having the ORU close to the antenna boosts the data performance in these high-profile buildings, where 3G/4G service is a must.	[redacted]
Radiation from mobiles and DAS antenna systems are a concern for the users of the building. The optically active DAS has the ORU installed close to the antenna; this will boost the uplink data performance. In addition there is a side effect; because the system calibrates the cable losses,	[redacted]

there is no attenuation of the signal from the antenna to the base station. Hence the mobile can operate using very low transmission power, because it does not have to compensate for any passive cable loss back to the base station in order to reach the uplink target level used for power control. This makes this approach ideal for installations in hospitals, for example. See Section 4.13 for more details on electromagnetic radiation.

The systems are fully supervised all the way to the antenna; there is full visibility of the performance of the DAS. Reliability is a concern, due to the number of distributed unit throughout the building. It is essential to select a supplier that can document good reliability and MTBF statistics. You also need to make sure that the location of all installed units is documented, so that they can be accessed for maintenance.

Care must be taken when installing these types of systems in moist, damp or dusty environments and they must be shielded accordingly. This is a particular challenge in tunnel installations, where the daisy-chained version of this type of DAS is often used.

4.5 Hybrid Active DAS Solutions

It is important to distinguish between the pure active DAS that we covered in the previous section and hybrid DAS solutions. As the name suggests, a 'hybrid' DAS is a mix of an active

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

DAS and a passive DAS. The passive part of the hybrid DAS will, as for the pure passive DAS, limit the installation possibilities, impact data performance on 3G/HSPA and to some extent dictate the design, due to installation limitations. 4.5.1 Data Performance on the Uplink The basic of RF design is to limit any loss prior to the first amplifier in the receive chain. The fact is that the passive portion of the hybrid solution between the antenna and the hybrid remote unit (HRU) will degrade the UL data performance. This is explained in more detail in Chapter 7. The impact of the passive portion of the hybrid DAS becomes a concern for 3G and HSUPA performance. 4.5.2 DL Antenna Power Even though the typical hybrid DAS produces medium to high power levels out of the HRU, the power at the antenna points will typically be significantly lower. The reason for this is that the power is attenuated by the passive DAS between the HRU and the antenna, but if you only service a few antennas and keep the losses low, you can obtain relatively high radiated power from the antennas. Antenna Supervision The small passive DAS after the HRU will give a high return loss back to the HRU; therefore it is often a problem for the HRU to be able to detect any VSWR problems due to the attenuation of the reflection from a	[redacted]

disconnected antenna. This, in practice, makes the antenna supervision nonexistent. Installation Challenges In order for the HRU to provide high output power levels, the HRU power consumption is quite high. Therefore you will typically need to connect a local power supply to the HRU; alternatively you can use a special hybrid cable from the MU to the HRU that contains both the fiber and copper wires feeding the DC power to the HRU. The need to use a local power supply for each HRU will add cost and complexity to the system, and more points of failure. Most likely, you will not be allowed to use any local power group, but are requested to install a new power group for all the HRUs in the DAS. Therefore, using the hybrid DAS type with composite fiber cables that also accommodate copper wires for power supply of the HRU is often to be preferred; however, there might be a concern in campus installations where you need to make sure that there is galvanic isolation between the buildings. Therefore copper cables might not be allowed to be installed between the buildings, due to grounding issues. Disregarding this might cause severe damage to the DAS and the buildings, and in the worst case start a fire. Owing to the high power consumption, the HRU normally has active cooling, and often a fan to help with ventilation. This might limit the	[redacted] [redacted] [redacted] thay vào đó [redacted] [redacted]

installation possibilities because of the acoustic noise, which is often restricted to the vertical cable	[redacted]
4.5.5 The Elements of the Hybrid Active DAS Refer to Figure 4.18. The MU connects to the low-power base station or repeater, and distributes the signals to the HRUs in the system. Typically the MU is connected to the HRU using optical fibers. The MU is the controlling element, the ‘brain’ of the system and also generates and controls internal calibration signals in the system, and then adjust gain and calibration levels to the different ports in order to compensate for the internal cable loss between the MU and HRU. However the system cannot include the passive DAS after the HRU; this part still relies on manual calculation and calibration.	[redacted]
The MU will also monitor the performance of the active part of the DAS system, and in the event of a malfunction is able to send an alarm signal to the base station so the operator can resolve the problem quickly. The system will not be able to detect any problems on the passive DAS, as there will normally be no antenna surveillance. It is possible to see the status of the active part of the system at the MU, on LEDs, an internal LCD display or via a connected PC.	[redacted]
Figure 4.18 Example of a hybrid active DAS, a mix of active elements	[redacted]

and distribution, combined with a passive DAS It will often be possible to access the MU remotely via modem or the internet using IP, perform status investigation or reconfiguration, and retrieve alarms in order to ease trouble-shooting and remote support.	[redacted]
Hybrid Remote Unit The HRU is installed throughout the building. It converts the optical signal from the MU back to normal RF, and the RF UL signal from the mobiles is converted and transmitted to the MU. The HRU will typically need to operate on medium- to high-output RF power, in order to compensate for the losses in the passive DAS that feed the signals to the distributed antennas connected to the HRU.	[redacted]
Hybrid DAS solutions are ideal solutions where you need high output power at the remote unit. This could be in tunnels; for 'T-Feed systems' see Section 4.8. It could also be sports arenas and multioperator systems where the composite RF power of the remote unit must be shared by many channels.	[redacted]
However, you must be careful with the high output power, and make sure that the uplink can track the coverage area of the downlink, or else the DAS will be out of balance. You must also be careful not to use the high power to only power one 'hot' antenna in the building; this could cause electromagnetic radiation (EMR) concerns (see Section 4.13) and cause	[redacted]

interference in the surrounding network.	[redacted]
The relative high cost of the hybrid DAS system normally makes it applicable only for only large structures with high traffic, and high revenue basis.	[redacted]
Often it can be effective to combine different type of DAS designs in a project, using passive DAS in one part of the building close to the base station, and active DAS in other more distant areas. This will often be a cost efficient option.	[redacted]
It is also possible to combine DAS solutions with macro sectors; for example an outdoor macro site might also be connected to an indoor DAS in the same building, for example where the outdoor sites are located on the roof.	[redacted]
The combination of different concepts will often enable the radio planner to design the DAS as economically as possible, and at the same time maximize performance. Once again it is all about using more tools in the toolbox; do not always rely on only one type.	[redacted]
In-line BDA Solution	[redacted]
It is possible to add an in-line bidirectional amplifier (BDA) to a	[redacted]

passive DAS in order to boost the performance of both the uplink and downlink on distant parts of the DAS, as shown in Figure 4.19. However it is a fact that all passive attenuation prior to the BDA, between the BDA and antenna, will seriously impact the noise figure on the system, limiting the uplink performance, which is especially a concern for 3G/4G indoor designs. Preferably the BDA should be installed as close as possible to the antenna. Refer to Section 7.2 for more details on how to optimize the BDA design.	[redacted]
As the name suggests, the BDA is a two-way amplifier with two lines, two amplifier systems, one for the DL one for the UL, and a filter system at both input and output.	[redacted]
In some applications the DC power to the BDA can be fed via the coax. This is very useful for tunnel solutions (see Section 4.9.2) and will save costs and complexity for power distribu-tion. In that case it is important to use passive components that are able to handle the DC power that are feed over the coax cable.	[redacted]
Owing to the remote location of the repeater, the only way to get an alarm back to the operations center is to use a RF modem located at the BDA location. Obviously this concept only works if the RF modem does not have to rely on the coverage signal from the BDA itself!	[redacted]

tributed Antenna Systems

It is possible to cascade BDAs, i.e. have more than one BDA in the DAS system. This could be done in a daisy-chain structure or even in parallel. However, it is important to be careful about noise control for this type of application. The noise increase in cascaded BDA systems can cause major problems with uplink degradation and have a serious impact on the performance of the base station and the network if you are not careful in the design phase. Refer to Chapter 7 with regards to noise calculation, and how to optimize the BDA design.

.2 Combining Passive and Active Indoor DAS

Often the most ideal solution for an indoor project would be to combine the best parts of passive and the best part of active DAS design (Figure 4.19). Passive DAS is cost-effective in basements, easy to install in the open cable trays available in basements and parking areas, and with low distances and only servicing a few antennas, the RF performance can be good. Active DAS is often more expensive, but it has the edge on performance at longer distances, and is easier to install in the more challenging parts of the building.

In the typical indoor project you will find that the equipment room you are assigned for the base station is located in the basement. Therefore it would be natural to cover the areas near the base station, parking areas, basement, etc.,

[redacted]

using a passive DAS with few antennas. This is ‘zone A’ (see Section 3.5.6), so you can get by with a relatively low coverage level. In the areas far from the equipment room, however, the office floors in the topmost part of the building, the high loss on a passive DAS might degrade the performance. Also, the instal-lation challenge with rigid heavy passive cables might be an issue, and too expensive. Then the natural choice would be to use passive DAS close to the base station, but active DAS in the more challenging areas. Then you can use the best of both applications, and avoid the downsides of any of them - now that is good use of the ‘radio planning toolbox’,--"" Indoor Radio Plann' There is one issue you need to be careful about when combining active DAS with a passive DAS, as shown in Figure 4.20 that is the noise power that the active DAS will inject into the passive system (base station). If you have a scenario where the uplink in the passive part of the DAS is the limiting factor, then the noise rise caused by the active DAS could degrade the uplink coverage in the passive part of the DAS. However the problem can be solved by carefully choosing the correct value of UL attenu-ator on the main hub of the active system. Refer to Section 7.5 for more detail on how to control the noise power.	[redacted]

Indoor and Outdoor Coverage

Often you will find that a building where a macro base station is located on the rooftop has surprisingly poor indoor coverage near the central core, especially on the lower floors. This is mainly due to the fact that the radio power is beamed away from the building by the high- gain antennas; the coverage inside the building has to rely on reflections from the adjacent buildings and structures. This is a problem especially in high-rise buildings that are not

Macro site

Figure 4.21 RF coverage in the building with the rooftop macro is low due to the need for reflections to provide indoor coverage

surrounded by high adjacent structures that can reflect the RF signal back into the building (as shown in Figure 4.21). In these cases it might make sense to use the rooftop macro base station as a donor for an indoor DAS. This saves the costs of an indoor base station, backhaul, etc. The capacity is trunked between the indoor and outdoor areas. If the traffic profiles between the two areas are offset, it can be a very efficient use of resources; see Section 6.1.9 for load sharing of the traffic profiles.

Minimize the Impact on the Donor Macro Sector

When you split a rooftop macro cell

[redacted]

[redacted]

into also serving an indoor DAS there are concerns that need to be addressed. One option is to split the power to one of the outdoor sectors to a passive DAS. However, this approach costs power and coverage area of the outdoor cell, especially if you need to feed a large indoor DAS.	[redacted]
The solution could be to tap off a fraction of the power (0.1 dB) to the macro cell to an active DAS (as shown in Figure 4.22). The advantage of this approach is that the outdoor coverage for the donor cell is maintained. The active DAS typically needs only +5 dBm input power, so only very little power needs to be tapped off from the outdoor sector.	[redacted]
Mind the Noise Power from the DAS There is one issue you need to be careful about, which is the noise power that the active DAS will inject in the UL of the macro donor sector. This can desensitize the receiver in the base station, limiting the uplink performance and impacting the UL coverage area, and on 3G the noise load will offset admission control. The problem can be solved by installing an attenuator on the uplink port of the active DAS and very carefully choosing the correct value of the attenuator. Refer to Section 7.5 for more detail on how to control the noise power and to Chapter 10 on how to optimize the performance.	[redacted]
Indoor Radio Plann'	[redacted]

Only a fraction of the power from the macro base station is needed, which will be more than enough to feed a large active indoor system. This makes this solution shown in Figure 4.22 applicable to many cases, like shopping malls and sports arenas.

However it is a fine balance; you must remember that all the downlink power and capacity used inside the building will also be radiated from the rooftop macro sector, causing interference load and noise increase in the macro sector. By configuring the settings correctly and carefully planning the indoor system to provide high levels of indoor coverage, it should be possible to minimize this effect, and make sure that the power control on the base station will power down the signals to the indoor users to a minimum.

4.7 Indoor DAS for MIMO Applications

In Section 2.6 we covered the basics of advanced antenna systems, utilizing MIMO so that we could optimize the data performance in the building. At this point in time it seems unrealistic from a practical viewpoint to implement more than 2 x 2 MIMO inside buildings, due to installation restrictions. As mentioned in Section 2.6 more advanced indoor antennas, utilizing cross polarized antennas, might ease the challenge of implementing MIMO in real life.

[redacted]

[redacted]

[redacted]

The key to good MIMO performance is a total separation of the MIMO links throughout the DAS, from the two antennas all the way to the base station, so it is not possible to use the same passive infrastructure at any point in the indoor DAS - that would destroy the isolation between the MIMO paths in the system. 4.7.1 Calculating the Ideal MIMO Antenna Distance Separation for Indoor DAS	[redacted]
Recent studies and calculations have provided the ‘ideal’ antenna separation of 3-7X; this also applies when implementing indoor MIMO DAS solutions in order to benefit from a maximum de-correlation between the MIMO paths created by the scattering of the indoor environment (Figure 4.23).	[redacted]
Using the guideline of a MIMO antenna separation of 3-7X we can calculate the ideal separations. We can calculate the wavelength (Lambda = X) of a given RF frequency: Wavelength X [meters] = 300 / frequency [MHz]	[redacted]
Using this formula we can calculate the ideal DAS antenna separation for MIMO deploy-ment inside a building, for the typical 4G/HSPA+ frequencies. Looking at the ideal antenna separation for MIMO in Table 4.3 we can easily conclude that practical implementations of the physical antenna separation for indoor DAS	[redacted]

becomes a real issue all the more so on the lower frequency bands due to the longer wavelengths at lower frequencies.	[redacted]
As we can see in Table 4.3 MIMO separation of five wavelengths at 700 MHz would take an antenna separation of 2.14 meters.	[redacted]
Figure 4.23 The typical MIMO deployment; we must watch out for antenna separation, and at the same time make sure both antennas have good SNR and the delay spread of the DAS is not too big relative to the two signal paths on the DAS. The ideal antenna separation distance is dependant on the frequency/wavelength and also the type of local environment	[redacted]
Table 4.3 MIMO antenna distance Make Both MIMO Antennas 'Visible' for the Users We want to make sure that we have sufficient de-correlation between the two antenna paths of 2 x 2 MIMO systems; we must ensure that we do not introduce too big a difference in the path loss in order not to impact upon power control and dynamic range. We must make sure that we do not place the antennas in the same cluster too far apart, which would introduce other potential issues, especially the the 'near-far' effect, where a mobile is close to one antenna.	[redacted]
In practice this will mean that we must make sure that both antennas are 'visible', for example when	[redacted]

implementing MIMO inside buildings, like hallways - and make sure that both antennas will beam down the corridors - as illustrated in the example in Figure 4.25.

It is very tempting to implement the antenna clusters as illustrated in Figure 4.24, thus uti-lizing MIMO between the two antenna clusters A & B themselves. However, we need to be careful; there is great potential for creating a ‘near-far’ problem when the MIMO antennas are too far apart. This will impact upon power control and might degrade the performance of the cell and minimize MIMO performance. The potential problem is evident in Figure 4.24; the mobile is near antenna cluster A - but is only in line of sight to the white antenna, the other part of the MIMO link is provided by antenna cluster B. This creates several concerns; the link loss to antenna cluster A is much less than the link loss to cluster B due to the distance and the increased number of walls for antenna cluster B. Another concern is the potential for inter symbol interference (HSPA+) due to the highly likely delay difference in the DAS to the antennas in cluster A relative to cluster B. It is unlikely that you have the same cable distance to the two clusters in the DAS, thus skewing the timing/phase between the two clusters of antennas, resulting in a degrading performance - potentially limiting the areas where the users can be serviced by 64QAM. This results in less throughput per area in the

building, thus working against the whole purpose of implementing MIMO in the first place; to increase the data speed per area of the building.

A better way of implementing the MIMO clusters of antennas inside the building can be seen in Figure 4.25; here both antennas in both clusters are placed to utilize the corridors, for

Figure 4.24 Example of layout of two clusters of MIMO antennas; at first glance it seems like a good idea, however we must watch out for potential ‘near-far’ issues

Indoor Radio Plann'

Figure 4.25 Example of layout of two clusters of MIMO antennas; at first glance it seems like a good idea, however we must watch out for potential ‘near-far’ issues

both antennas in both directions. This will result in a much more uniform RF level performance between the two MIMO paths, at the same time taking advantage of the scattering inside the building. This also results in less inter symbol interference, maximizing the areas where high order modulation 16/64QAM can be utilized, boosting performance inside the building.

It is highly recommended that one keep this in mind when planning the antenna clusters for MIMO in hotspot areas inside the building - where data use is high, and where you must strive for the best possible performance. For more detail about hotspot antenna planning inside buildings, refer to Section 5.4.1.

Other MIMO Concerns

[redacted]

[redacted]

[redacted]

We also must make sure that we have a good signal to noise ratio on both MIMO paths, if not then performance would suffer on both paths.
In real life the ideal antenna separation would also depend on the delay spread and scatter of the local environment; it might well be that we will gain more experience in the future, so we could recommend one separation distance for an open indoor environment, another for a more dense environment with more walls, etc.

Also please note that for multiband solutions it will be the lowest frequency that dictates the antenna distance.

Indoor DAS Antennas Designed for MIMO

Most manufacturers of indoor DAS antennas also produce antennas designed for MIMO operation. These antenna types look like a standard SISO antenna, but actually contain two separate antenna elements inside the same single enclosure (radome). The DAS feeds the two antennas via separate antenna connectors. The major advantage is that these MIMO antennas only appear as one single antenna installation, unlike the examples in Figures 4.24 and 4.25. This is

Directional MIMO antenna

Omni MIMO antenna

Seen from side (inside)

Figure 4.26 X-pol antenna in one Radome - Omni and directional

important when obtaining permission

[redacted]

[redacted]

for the physical installation of the DAS. So in real-life installations, it helps with implementing the DAS antennas needed for MIMO support, as you halve the number of antennas needed in the building, with considerably lower visible impact in comparison with using two separate antennas at each of the antenna locations to support MIMO.

However, one might be concerned about the de-correlation performance and whether the MIMO performance will be effective enough. The concern has to do with the lack of physical separation of the antenna elements, as the two antennas reside inside the same radome, which could compromise the required inter-antenna distance according to Table 4.3. However, this inter-antenna distance is based on two antennas with the same polarization. The MIMO antennas shown in Figure 4.25 are certainly close to each other, but they use different polarizations with 90° relative offset (+/- 45°). This polarization separation will actually ensure sufficient MIMO separation of the scattered signals in the building and create sufficient decorrelation between the two individual MIMO paths. The deployments I have see with this approach so far have also been performing well on MIMO. We usually call these type of antenna 'X-pol' or 'cross-polarized' antennas.

Uniforrorm MIMO performance

One of the big performance advantages of these X-pol antennas is

[redacted]

[redacted]

[redacted]

the fact that they will typically have uniform MIMO performance. Therefore, an X-pol MIMO omni antenna will have 360° MIMO performance in the service area, relative to the antenna location (see Figure 4.27),

Figure 4.27 Floor plan (office) with MIMO and X-pol, same MIMO performace in 360° service area

unlike the two distance antennas used separately, as in Figures 4.24 and 4.25, which will typically have lower MIMO performance in the direction in which the two antennas 'line up' with the direction of the mobile. However, this also depends on the local environment: in a vcluttered environment, there will most likely be sufficient reflections to compensate, but this could be more of a challenge in a relatively open area. Figure 4.27 shows two MIMO omni antennas deployed in a typical office floor. Having only a single X-pol MIMO antenna to deploy will make it more likely that you will have an installation location for the antenna with clear 'visibility' for both MIMO paths down the hallways, and, in addition, the X-pol MIMO antenna will have 360° MIMO performance.

MIMO upgrades of SISO systems

There are occasions when it would be convenient if you could upgrade existing SISO DAS to MIMO without the need to double the DAS infrastructure, install more antennas and pull more cables throughout the

[redacted]

[redacted]

[redacted]

structure. Ideally, you would select every other antenna for MIMO1 and the alternate antennas for MIMO2 etc., thus interleaving the existing SISO antennas to create a MIMO DAS in an existing installation. The success of this approach depends on several factors:	[redacted]
• It must be ensured that the footprints of the interleaved antennas overlap in a sufficient area	[redacted]
- in the areas with no overlap there will only be SISO performance.	[redacted]
• The C/I of both antennas in a MIMO system must be sufficient; the performance will be dictated by the C/I of the worst antenna.	[redacted]
If we consider the example in Figure 4.28, an original SISO design for an office area, we could use one antenna for MIMO 1 and the other for MIMO 2 - the MIMO area will be limited to where the two antennas overlap with sufficient signal level. In this example, most of the	[redacted]
Antenna A Antenna B Figure 4.28 Floor plan (office) with MIMO "overlap" of two SISO antennas	[redacted]
MIMO serviced area falls in the hallways and service areas, not in the offices where we expect most of the data load, and where the benefit of MIMO is needed. So the upgrade principle might not be very attractive in this type of application.	[redacted]
But there might be other building types where this approach is more applicable (such as the example in	[redacted]

Figure 4.29), typically with large open spaces that can ensure a good overlap of the two MIMO antennas. In the areas with insufficient coverage from one of the antennas, there will only be SISO (Figure 4.29).	[redacted]
We just concluded, based on the office floor application in Figure 4.28, that we would have a limited MIMO performance area, due to the limited overlapping area of the two MIMO antennas. However, if we use the same approach and upgrade an existing SISO DAS by ‘interleaving’ the existing antennas in open areas, where it is likely to have greater overlap, we might have a more extended service area for MIMO.	[redacted]
Figure 4.29 shows an example where the upgrade of an existing SISO system might per-form well. This is a conference auditorium with four existing SISO antennas, labeled 1-4.	[redacted]
We have now upgraded this DAS to use two antennas (antennas 1 and 3) for one MIMO branch, and the other two (antennas 2 and 4)for the other MIMO branch. As shown in Figure 4.29, most of the area actually performs as MIMO (gray area) where there is full service overlap - only in the more distant corners are antennas 1 and 2 not able to reach and overlap with antennas 3 and 4 (white area) and only antennas 3 and 4 cover SISO service. The large MIMO area (gray) is mostly due to the large overlap, thanks to the open aspect of the venue.	[redacted]

A similar approach can be seen in Section 14.2.3 where we look at a large, open, hall structure, like a warehouse, in more detail. This approach could also be applied in parking areas, although it is less likely that you will need MIMO to support high-speed data services in parking areas.

It is always recommended to do a real MIMO design if you start from scratch and are designing and installing a new DAS, but sometimes, in open areas of the buildings, you might get by with an upgrade from SISO to MIMO as described. In areas such as exhibition halls, conference areas, and sports arenas, a relatively simple upgrade like this might suffice (for further detail, see Section 14.2.3).
Indoor Radio Planni
MIMO performance
two antenna overlap
SISO performance
serviced by a single antenna

Figure 4.29 Floor plan (large conference hall) with MIMO "overlap"
Although you do not add more antennas with this approach, you will obviously need to pull extra cables to support the two fully separated branches - one cabling line/active DAS for MIMO A and one for MIMO B. If the two branches interconnect at any point in the installation, by accident, the MIMO performance will lost for that cell. So be careful with the

[redacted]

[redacted]

[redacted]

documentation and installation discipline and supervision. I sometimes recommend that the installer mark all the different components in two different colours, to avoid mixing up the two individual MIMO paths.

[redacted]

4.7.3 Passive DAS and MIMO

The whole purpose of introducing MIMO inside buildings is to maximize data performance on both the downlink and the uplink. As we have learned in Chapter 7; the more loss we have between the base station and the DAS antenna the worse the Noise Figure will be and would limit data performance on the uplink. So, even considering Passive DAS for MIMO inside buildings (Figure 4.30) contradicts the goal itself. It is a fact that you will need total isolation of the different paths in the DAS for successful MIMO operation, in reality you would need to install two parallel Passive DAS installations, increasing cost and implementation time. On top of this, it is a challenge to ensure that you use the same cable distance on both links in the Passive DAS to avoid inter symbol interference that will degrade both the uplink and downlink (HSPA+).

Figure 4.30 An example of a Passive MIMO DAS; in real life Passive DAS would rarely be considered for supporting MIMO, especially in large indoor DAS deployments

[redacted]

You would still be able to operate 4G on a passive DAS with single antennas

[redacted]

(SISO mode, see chapter 2.6.1), provided the link budget is confirmed - but obviously not MIMO unless you install a parallel DAS.

4 7.4 Pure Active DAS for MIMO

As described in Section 4.4.3 pure Active DAS has many advantages: ease of installation, 100% visibility on the O&M state of the system - most of all that the remote unit contains the last downlink amplifier and the first uplink amplifier in the system, thus maximizing the downlink coverage and providing a good Noise Figure on the uplink - boosting data speed in the cell.

Pure active DAS, as is shown in Figure 4.31, is a perfect choice for HSPA+/4G MIMO DAS deployments for several reasons.

First of all, we have all the advantages as described in Section 4.4.3 connected with MIMO performance.

The MIMO DAS illustrated in Figure 4.31 supports two independent MIMO paths for both the downlink and the downlink (2 x 2 MIMO). The eNode-B connects with 2 x 2 MIMO to the Master Unit, from the Master Unit throughout the system - via the Expansion Unit to the Remote Unit the system relies on one set of optical fiber, cable and units. Within the system, the 2 x 2 MIMO paths are kept 100% separate with perfect isolation. As illustrated in Figure 4.31, only the interface between the Master Unit and the eNode-B, and the

[redacted]

interface to the two MIMO antennas are two independent cable systems. Within the system the two MIMO paths are kept separate by mixing down the two paths to separate intermediate frequencies for

Figure 4.31 The typical Pure Active DAS for MIMO - the two MIMO paths are kept separate when transported in the Active DAS, by means of separate intermediate frequencies for Analogue DAS, or separate data streams for digital active DAS

tributed Antenna Systems

analogue active DAS, for digital distributed DAS in separate data streams. It is recommended that one keeps the system 'symmetrical' throughout - so the same cable distances for the jumpers and interface between the Master Unit and the base station (eNode-B) and the same type and lengths of jumpers from the remote units to the antennas.

Hybrid DAS and MIMO

In Section 4.5 we covered the basic functions of the Hybrid DAS, i.e. a distributed antenna system that is a mix of an active DAS (with high power Remote Units) feeding a passive DAS. We can also use a Hybrid DAS to support MIMO, as illustrated in Figure 4.32.

Being a Hybrid DAS it has all the disadvantages of the Passive DAS and all the advantages of the Active DAS; the two MIMO paths (2 x 2) are fed to the Master Unit - separated and transmitted over optical fiber to the

[redacted]

[redacted]

[redacted]

[redacted]

high power Hybrid Remote Unit. After the Remote Unit we connect two parallel Passive DAS that distribute the signals inside the building. As described earlier it is important to employ a symmetrical design and implementation of the passive system in order not to introduce any time skewing of the two paths.	[redacted]
In practice we will encounter a frequent need for upgrading existing DAS installed in build-ings. Keeping in mind that we need to make sure that we have a symmetrical deign of the two MIMO paths, the question is whether this is possible at all; to reuse the existing DAS as one path in the MIMO system and install a new DAS in parallel. In practice, it would be worthwhile to consider a complete new DAS design and new implementation for the following reasons:	[redacted]
• The DAS has been installed for some time, likely designed for previous generations of mobile systems, thus the link budget and antenna locations do not match the requirements and link budget for (3G)HSPA+/4G.	[redacted]
• The (Passive) DAS was designed for lower frequencies, so it will have high losses degrading both the downlink power and the uplink Noise Figure, compromising 4G performance on the higher frequencies.	[redacted]
• The lack of documentation might make impossible to install a	[redacted]

‘mirror’ DAS, a truely 1:1 copy that will fulfill the requirements of good symmetric 2 x 2 MIMO operation.

- The antenna locations do not support dual installation of antennas.
- The existing DAS might be supporting FDD, and you want the new DAS to support TDD - so the constant downlink signal from the FDD system might block the 4G-TDD system when in receive mode.

[redacted]

- The existing antenna locations might not provide sufficient isolation to perform on the higher modulation schemes needed for 4G. For more details of optimizing the isolation refer to Section 3.5.3.

[redacted]

Given these arguments and other good reasons, it is normally worthwhile considering wip-ing the slate clean and simply designing and installing a completely new system - often a pure Active DAS to support 4G/HSPA+(3G) MIMO systems. This is especially so when considering relatively old DAS implementations designed originally for 2G.

[redacted]

that all Indoor DAS solutions should be implemented based on a business case evaluation (see Section 5.1). However, sometimes it turns out that the traffic in the indoor area that requires coverage improvement does not justify the deployment of a new base station with all the cost associated with this, as well as the backhaul/transmission and upgrade on network elements that supports this new base station.

[redacted]

Where you need only to improve

[redacted]

coverage and not add significant capacity inside the building then feeding the DAS with an off air repeater could often be a viable option.	[redacted]
Repeaters typically serve the purpose of providing sufficient signal level inside a building, providing dominance inside a building that lacks single server dominance and in general to improve the data throughput of the service inside buildings. A repeater needs no connection to the network in terms of transmission interface, but has to rely on an available air signal in the area from an existing base station, pick up this service and re-radiate this existing cell inside the building via a DAS.	[redacted]
You could say that the basic purpose of the repeater is to circumvent some of the path loss between the serving cell and the mobile inside the building. So if the repeater installation can compensate for some of the link loss we can improve the link budget and get a higher quality of service inside the building, perfect! Repeaters are a strong tool, you can solve many problems, but if you are not careful, repeaters can create many more problems than you actually solve - because even if you can see an instant improvement of the RF service signal level inside the building being serviced by the repeater, the impact on	[redacted]

the donor cell and other cells could still be negative and affect performance.	[redacted]
Repeaters Should be a Strategic Decision	[redacted]
Quite often repeaters are deployed to provide a remedy for one or more problems, such as VIP location, an indoor DAS where the mobile needs to implement a swift solution to solve the problem. But before implementing that first solution, one should consider the general approach carefully, the different repeater types that could be used and, moreover, remember that the repeater will be another network element, that should be monitored.	[redacted]
There have been far too many cases of networks where a few repeaters has been deployed in ‘panic’ to solve a pending problem, soon to be followed by yet more similar deployments, only to realize that one to two years down the road, you might have ten to thirty repeaters deployed. Along the way you might have learned some lessons. And now, you realize that you forgot to consider the general impact of repeaters on your network, the impact on the performance of your existing macro net, how to optimize the setting, how to select the appropriate repeater - and one of the most important parameters, remote monitoring of these new network elements	[redacted]
Monitoring Repeaters Repeaters, like any other active	[redacted]

network elements, should be integrated in the mobile oper-ator's network performance monitoring system (the NOC/OMC). Potentially, a faulty repeater could degrade the service quality in a widespread area of your network if it is not configured correctly, or if it becomes faulty, etc. Therefore you must make sure that you can monitor performance, the status of the remote repeater, and if needed switch the repeater system completely off remotely until these problems are solved. It is not recom-mended to implement any repeaters in your network that you cannot monitor or control and monitor 24/7.

Also, changes in the macro Donor cell might trigger a need for changes of the repeater set-tings and configuration, such as change of frequency, etc. Most repeaters are remotely con-trolled via an internal wireless modem and rely on a standalone platform in the network operations centre for control and monitoring of all repeaters implemented. So when selecting repeaters, it is important to always consider the impact of the full implementation over several years, as well as the crucial monitoring system and platform.

5 h 02 5-11

4.8.1 Basic Repeater Terms

Let us start with the basic terms in a typical repeater's application (see Figure 4.32). The Repeater itself (Figure 4.33) is a BiDirectional Amplifier (BDA) that will amplify the

[redacted]

[redacted]

[redacted]

Uplink and Downlink of a specific part of the spectrum, simply passing the signal from the outside network to the indoor system, and in reverse for the Uplink amplifying the signal from the mobile inside the building. It is highly recommended that one selects a repeater where the gain on the UL and DL can be manually configured independently. It is also recommended that one selects a repeater where one can select the exact channels/bandwidth of spectrum one requires to support via the DAS inside the building. A more detailed description of the different types of repeaters can be found in Section 4.8.2.

Donor cell

Figure 4.33 Principle terms of a typical repeater application designed to provide indoor coverage and Capacity

The Donor antenna (Figure 4.33) is also sometimes referred to as the ‘Pick-up Antenna’ this antenna is typically a highly directive antenna that is directed towards the existing macro cell - the Donor cell that is selected to provide signal to the indoor system via the repeater. Since we are normally relying of line of sight service from the Donor cell we must

[redacted]

[redacted]

make sure and use the same polarization for the donor pick-up antenna as used by the Donor cell. This can be a challenge if the Donor cell uses ‘air combining’ - utilizing a cross polarized antenna, one polarization fed by TRX one, the other polarization fed by TRX two. Then you might pick up a good signal on one of the TRX, but when traffic is shifted to the other; the polarization loss of signal level will impact upon performance.	[redacted]
The exact installation location of the Donor antenna in the building’s structure is crucial for the performance of the repeater-DAS solution. Not only will we have to ensure that we can reach the desired service level, but we must also place the antenna in such a way that we maximize the isolation between the service antennas inside the building and the Donor antenna. Moving the location of the Donor Antenna itself in the building is often a part of the optimization process, and you have to take advantage of structures in the building and surrounding buildings in order to maximize the Donor Signal, minimize unwanted signals and maximize isolation by carefully selecting the optimum type of donor antenna as well as the ideal location on the building for the installation. You should strive to have line of sight to the Donor cell from the donor/pick-up ant	[redacted]
The Donor Link Loss (Figure 4.33) is	[redacted]

obviously an important part of the link budget calculation and you typically will measure the signal level from the Donor cell in order to calculate the Donor Link Loss for your link budget.

Be careful when you measure the signal level at the location of the donor antenna in order for you to estimate initially the required repeater gain and directivity (gain) of the donor antenna. If you use a standard portable mobile phone with test software and apply the direc-tivity (gain) of the donor antenna and use that as a basis for your link calculation you are likely to make a mistake. A mobile with a simple antenna with low directivity will pick up a multi path signal and combine this with a signal level due to the internal equalizer/rake reciever in the receiver. However, when using a highly directive (high gain) antenna as a donor antenna you have virtually no multi path, and a lower donor signal level.

Bear in mind that the link loss will not be stable, but be prone to fading and reflections, etc. This dependstypicaly on the local environment, and the link will normally be more unstable over longer distances. It is highly recommended that one rely only on line of sight Donor cells, in order to minimize fading and to have a more stable system.

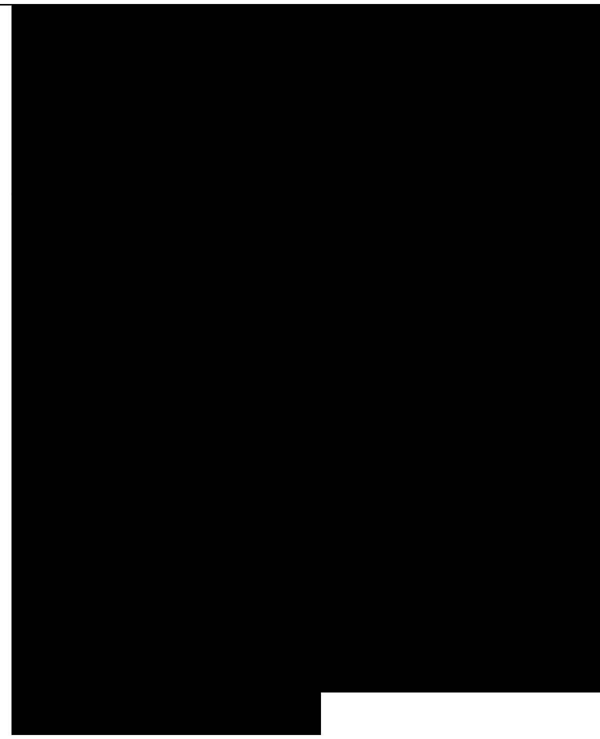
onor Cell

[redacted]

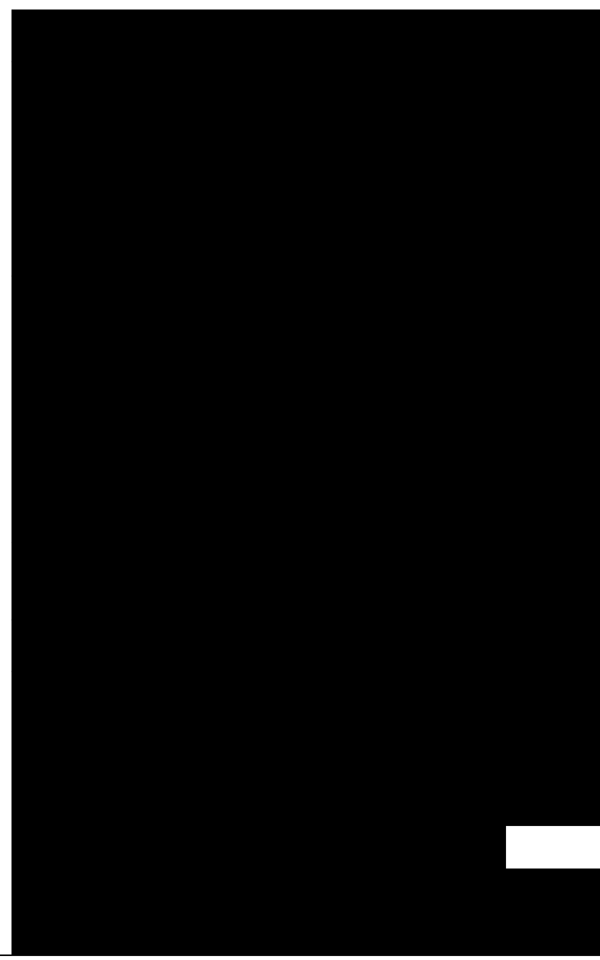
[redacted]

The Donor cell (Figure 4.33) is the existing macro cell that is selected to provide coverage and capacity to the indoor DAS via the repeater. This Donor cell will then share its existing coverage area to include the indoor area that is added to the service area via the repeater and indoor DAS. Indoor Radio Plann Keep in mind that you bring the cell inside the building via the repeater and the DAS, so if you select a cell that normally does not service this geographical area, you will need to adjust neighbor lists, etc accordingly. The Donor cell might also suffer from UL noise loading from the repeater and DAS - depending on the NF of the repeater-DAS, the UL gain you set in the repeater and the link loss. The impact of this noise load in terms of noise power increase is covered later in this chapter (Section 4.8.3) and in general in Chapter 7. It is important to select a suitable donor cell with a sufficient signal level, but also with a sufficient quality. If the signal to noise ratio on the Donor Cell is bad, no matter what the pickup level, the repeater will never be able to improve quality. It is always recommended that one selects the Donor with the best S/N quality, rather than on the highest signal level and one should strive to achieve a quality of donor signal of a minimum 20 dB signal to noise ratio or It is very important to realize that the pickup antenna (Figure 4.33) is a crucial part of the repeater solution,	[redacted]

and potentially the problem! The donor antenna is the Achilles heel of the solution, not only should it be of sufficient gain to pick up the appropriate donor cell with the desired quality, but also directive enough to ensure that you do not pick up several potential donor cells in the same signal range. If this happens you create a large soft handover zone inside the building (3G) or C/I problems that result in a degraded service. Therefore it is recommended to make sure that one has at least 10 dB single cell dominance, preferably more than 15 dB of the desired serving cell.



The indoor DAS (Figure 4.33) could be any type of DAS system as described in Chapter 4: Passive, Active or a combination (Hybrid). The indoor DAS will then service the mobiles inside the building by re-radiating the selected Donor Cell picked up by the donor antenna, amplified by the repeater on the downlink, and vice versa on the uplink. We will have to cal-culate a separate link budget for the indoor service range - to estimate the maximum allowable link loss on from the service antennas to the mobile, the Service Link Loss - more detail on Link Budget calculations can be found in Chapter 8. One should strive to have a minimum of 20 dB signal to noise ratio on the Donor cell that the repeater picks up.



The repeater will have separate

amplifiers for the Uplink and Downlink with separate gain settings - more detail on this is to be found later in this chapter. Be careful not to offset the balance between UL and DL gain too much, this can affect power control in the network. Isolation is a very important issue when designing repeater solutions - isolation is defined as the loss (in dB) between the output of the repeater and the input of the repeater. tributed Antenna Systems This includes all gain and losses of donor and service antennas, cable losses, DAS gain (active DAS)/loss (Passive DAS), etc. Service antennas are a crucial parameter when designing repeater solutions. One could consider this as the Achilles heel of repeater solutions. In order for the repeater to radiate a desired power via the DAS inside the building we must make sure that the isolation will be better than specified by the repeater manufacturer. Typical requirements would be a minimum of isolation of 10 to 15dB plus the gain setting. The margin is required in order to prevent the amplifiers in the repeater from oscillating, via positive feedback - by the repeater amplifying its own signal.	[redacted]
In practice, you must ensure that the isolation will remain unaffected by changes in the local environment near the donor or service antenna.	[redacted]

There are instances where a repeater solution will be affected by the opening of windows in a building. Due to the metallic coating on the window, there was excellent isolation - until the window was opened, then the repeater turned down the gain automatically and the users lost service inside the building.

You can check the isolation by applying a test transmitter/Sitemaster to the DAS (at the repeater output connector) and measuring the power you get at the input at the repeater. However, leakage between the test transmitter and donor antenna is an issue. In practice, one might consider deploying a small test transmitter at the expected 'worst case' service antenna inside the building, and measuring the power one picks up at the repeater input. One must use the directivity of the donor antenna and physical objects in the building such as elevator towers, ventilation shafts, etc, to help maximize isolation; this can sometimes be a considerable challenge.

Some repeater types come with intelligent isolation enhancing features that will limit the need for physical isolation considerably.

Isolation concerns for repeater solutions that have to rely on high gain can be quite challenging, and even reflections from distant objects; buildings, hills. etc more than several kilometers away can be a problem.

[redacted]

[redacted]

[redacted]

It is very important to be aware of any areas inside the building where the mobile might be able to 'see' the direct signal from the Donor cell as well as the Donor cell via the repeater system. This will cause a multipath signal and one must ensure that the delay between the two signal paths can be handled by the receiver and the equalizer. For 3G/WCDMA systems the rake receiver will use one finger for each of the signals; this can be observed on the test mobile, on 2G it can be identified by frequent, rapid changes in TA (Timing Advance) step -due to the delay offset by the repeater in its coverage area - adding to the TA used by the mobile. Service Link Loss As when you design a standard indoor DAS you will have to do link budget calculations to estimate the UL and DL service range for the required wireless service on the DAS. The DL is pretty much the same calculation as that for a normal DAS; you have a specific output power from the DAS antenna, then you can calculate the expected service range. On the UL you will have to include the NF and gain performance in the DAS, the repeater and the link back to the base station. For DAS systems inside a building that are to provide a high speed data service using 64QAM such as 3G/HSPA and 4G it is very important	[redacted]

to make sure and select a high quality repeater that supports this modulation accuracy, if not then the service inside the building will be limited in terms of throughput, not due to lack of signal level but to lack of phase quality to support 64QAM. Output Power Output power is obviously an important parameter when designing an indoor repeater solution that feeds a DAS, especially if you are feeding a passive DAS (Section 4.3) where the repeater needs to drive all the losses in the passive cables, splitters, etc. It is less important if the repeater feeds an Active DAS (Section 4.4) where the DAS itself has integrated amplifiers. One has to keep in mind that even though the output power of the repeater is specified to a certain level, the actual output power, in practice, is a result of the input signal strength, the gain and the limitation on the isolation. Example: Calculating the Output Power from a Repeater Let us look at a simplified example of a 3G/WCDMA Repeater application and estimate the output power we can get in practice (Figure 4.33). Repeater Data Output Power @ 1 CH: 35 dBm (CPICH 25 dBm) Gain 60-90 dB in 1 dB Steps Isolation is measured to 86 dB Measured CPICH from the Donor at the repeater input (including donor antenna gain, etc): -75dBm.	[redacted]

This repeater drives a passive DAS with 17 dB of loss to the Service antennas and we want to achieve a CPICH power of 5 dBm from the Service antennas.
We can then calculate the desired CPICH power we need from the repeater (assuming CPICH is -10 dB)

Desired CPICH Power = DAS Loss –

CPICH@ServiceAntennas
-55.5 Desired CPICH Power = 17dB - 5dBm = 12dBm
Surely this should be possible, considering that the CPICH Power from the repeater is specified to 25 dBm, but we must take the isolation and the gain into account.

In order to achieve 12 dBm we can calculate the needed gain, knowing the input power to the Repeater.

Needed Gain = Input Signal-Output Power Needed Gain = 12dBm-(-75dBm) = 87dB.
The repeater has up to 90 dB of Gain so this should be possible? Actually no, it is not possible!
Considering that we have measured the isolation to 86 dB, and the repeater manufacturer requires that the gain must be set at 10 dB lower than the isolation we will be limited to a gain setting of 76 dB (86 - 10).
We can now calculate what the maximum CPICH power will be when considering the isolation:
CPICH Output = CPICH Input +

[redacted]

(Isolation -10) CPICH Output = - 75dBm + (86dB - 10dB) = 1dBm. Thus we can conclude that the CPICH power in this case will be limited by lack of isolation and not the power capabilities of the repeater. In this example we needed +5 dBm CPICH power from our DAS antennas, but can achieve a maximum of +1 dBm. So in order to make the system comply with the design specifications we must optimize the isolation or add a few more antennas to the indoor DAS. 4.8.2 Repeater Repeaters come in various types: high power, low power, mini repeaters, band selective, channel selective, ‘Automatic’ configurable versions, etc. Let us have a look at the main features and concerns with some of the more common repeater types. It is a very basic and important question: what type of repeater should you select for your application? Obviously, this will depend on the precise applications, so let us have a look at some of the common concerns, pros and cons of the various types of repeater. Wideband Repeaters Wideband/broadband repeater is a generic term used to describe a repeater that will cover a broad section of spectrum, typically the whole section of a specific band. So, a broad band 3G 2100 repeater will typically	[redacted]

cover the entire 60 MHz of the 2100 MHz 3G spectrum. If we consider the repeater deployment scenario in Figure 4.33 where we are designing a repeater solution to provide coverage inside a building for Operator A; we should be careful and consider not choosing a Wideband repeater. The reason is that Operator A is the most distant base station, and the nearby base stations from Operator B and Operator C that are relatively close to the building where we are deploying the repeater solution.

In this example the potential issue is quite evident when considering the wideband support illustrated in Figure 4.33. The risk is that the donor antenna that points towards the Donor cell from Operator A (Figure 4.33) also points directly at several unwanted cells from Operator B and Operator C and selecting a wideband repeater for this application could result in a rise in noise and receiver blocking due to the high signal levels from the unwanted signals, that fall within the supported spectrum of the wideband repeater. The risk is potentially also present on the UL, the noise generated by the UL amplifier could cause a rise in noise in alien base stations very close to the donor antenna. This will also impact upon base stations not belonging to the operator who deploys the solution.

So, we can conclude that a wideband repeater is less suitable for a single operator solution. However, sometimes we have to provide

[redacted]

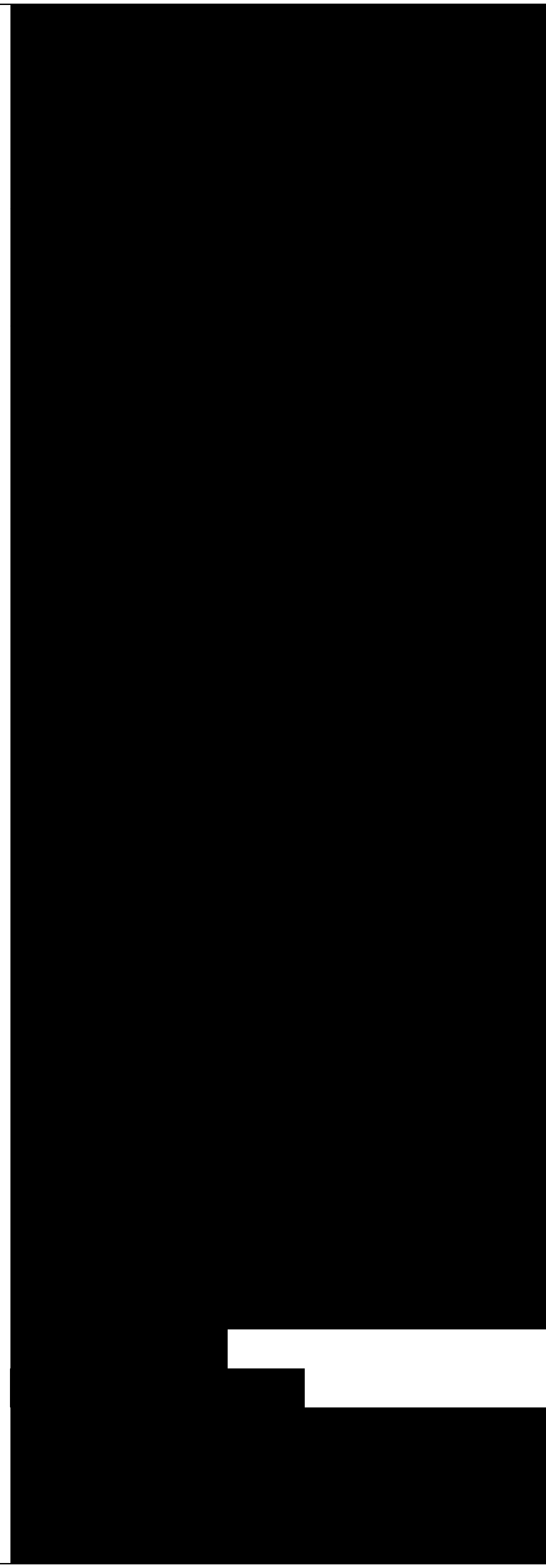
[redacted]

coverage for several operators feeding the same indoor DAS; for this application it is tempting to use a wideband repeater to cover all operators. Nevertheless, it will be recommended to use individual channel selective repeaters to feed the system - in this case gain settings, etc. can be set individually and adapted for each of the donor links. Band Selective Repeaters As the name indicates, a band selective repeater will support a sub-section of a specific spectrum. Normally, a band selective repeater can be configured to support any section of a given spectrum; one will have to configure the ‘band start’ and ‘band stop’ frequency and the repeater will then support the spectrum within these settings for band support limits. Typically a mobile operator will configure a band selective repeater to support the specific band that specific operator uses, this will ensure that the mobile operator is more or less independent of frequency changes in the donor base station, frequency hopping, etc. When using this type of repeater we must still be careful, as the example in Figure 4.34 shows; in this example we have configured a band selective repeater to support Operator C, and as we can see in Figure 4.34 Wideband Figure 4.34 The different repeater options in terms of band support, as compared with the set up in Figure 4.33	[redacted] [redacted]

there is a relatively low donor signal from Operator C of about 95 dBm. Near the building where the repeater supporting Operator C is being deployed, Operator B has a strong base station nearby that is using a frequency just on the lower edge of Operator C’s band. The band selective repeater has some ‘roll off’ in terms of gain below the selected ‘band start’ fre-quency. In this case it will mean that the strong signal from Operator B will also be amplified and feed to the DAS solution, or even worse it might skew the uplink gain, add noise or even block the receiver of the repeater. The solution to this problem would be to move the ‘band start’ frequency up so the strong signal from Operator B will not pass through. But this will also mean that the gain on the lower part of Operator C’s spectrum will be low, and this could be a problem if the donor base station changes frequency. For 3G systems where operators typically have a coherent band of one to three channel bands selective repeaters could be an ideal solution, bearing in mind the potential ACIR problem with adjacent frequencies. Some 2G operators have segments of sub-bands interleaved between the segments of other mobile operators, in this cases band selective repeaters can be a challenge to deploy.

Selective Repeaters

In many cases the Channel Selective Repeater will be an ideal source to feed an indoor DAS. As illustrated in Figure 4.34, one can select the exact



donor channel one wants to pick up for your service. This means that one can be virtually unaffected by the other signals illustrated. This makes the system relatively easy to configure and optimize; however one must remember that if the Donor cell changes frequency the repeater will have to be reconfigured, if not the indoor DAS that is feed by the repeater will be out of service. In some networks, such as 2G, one must also pay attention and ensure that the repeater is not fed by a donor that uses frequency hopping on channels not supported by the repeater. For 3G systems one will typically be sure to support both the first carrier (used currently for R99 3G/voice) as well as the second channel used normally for HSPA. For 2G systems one must make sure that the repeater will support all channels used by the Donor cell, both the channel for the BCCH as well as the frequency used by all the THC channels in the cell. Some more advanced GSM7DCS repeaters can actually decode System information and track and follow the associated TCHs when there is a change of frequency in the Donor cell.

[redacted]

‘Lunchbox’ Repeaters

There are many small repeaters on the market, typically of lunch box size, with a DC power supply, integrated service antenna and a connector to connect to an external donor antenna. These repeaters apply different levels of ‘automatic configuration’ in terms of gain; some have some sort of

[redacted]

‘intelligence’ designed to limit support to specific operators, etc.	[redacted]
In general, these repeaters should only be considered for ‘single room coverage’, and given their automatic settings are not ideal to feed a DAS since you have no control of any setting or configuration. One is not a big fan of these types of solution, but acknowedges that they are fast and ‘easy’ to deploy - however, remember that any repeater will have an impact on the Donor cell in terms of noise load on the UL, and one would prefer to be in control of that impact, and not leave it to a low cost ‘automatic’ device. But then again, new versions and types are constantly being introduced so the future might bring some good solutions even for this type of repeaters. In recent times, the market has seen a new type that utilizes an internal RF link (using the Wi-Fi open spectrum) to link up with a ‘donor unit’, located near the window with one or several ‘service’ units that provide fill in coverage at the core of the building.	[redacted]
Primarily to avoid the problem with lack of isolation between the donor and the service antenna a special type of repeater can be used; ‘the Frequency Shifting Repeater’. As the name indicates, this repeater uses different input and output frequencies. Actually, this repeater solution is a set of units, one unit located at the Donor	[redacted]

cell; this unit is hard wired to the donor site, converts the donor cell band to another frequency channel on another band (a band that is licensed to the operator) and transmits this converted band over the air-link, to the remote site (located at the building/are we want to cover). The remote repeater unit then picks up the converted channel, re-converts to the same frequency/channel of the Donor cell and transmits this to the indoor DAS. This solves the isolation challenge due to the fact that the input frequency band/channel and the output frequency band/channel operate on different frequencies. This makes it possible to apply high gain repeaters, with high output power, in applications where assuring sufficient isolation is a challenge. Obviously, the mobile operator must have the right to operate on both bands, the ‘service channel’ i.e. the channel used by Donor cell and thus the remote repeater system, as well as the band used to transmit/link the Donor cell and the remote repeater system.	[redacted]
Repeaters are a strong tool, with relatively low investment and are quick to deploy, but like any other good tool it is important to know how, when and where to use them - and when not to.	[redacted]
Generically, a repeater (Figure 4.33) is merely an amplifier, a bi-directional amplifier that will extend a coverage footprint from a Donor cell into an	[redacted]

area which the Donor cell cannot reach by its own, in our case inside a building. Repeaters come in various types, as described in this chapter, but there are some main performance considerations that are important to remember when designing with repeaters.	[redacted]
Repeater based solutions are not 'install and forget' solutions, one needs to monitor and track the performance of the repeater and the DAS carefully. Not only can a malfunction in a repeater solution cause problems for the users being serviced by the repeater inside the building, but a repeater could also potentially degrade the performance of the Donor cell if any errors occur or if the repeater solution is not installed or tuned correctly. Even if you have good coverage inside the building, the repeater could still degrade the performance of the Donor cell. So once a repeater is deployed it is recommended that one monitors the performance of the Donor cell closely over some weeks in order to evaluate the impact of the repeater.	[redacted]
It is highly recommended only to user repeaters where one has operation and maintenance access and alarm monitoring, and if needed, shut it down remotely - this functionality is typically implemented via an integrated wireless modem, and controlled by the mobile operator	[redacted]

from the operation and maintenance centre. It is a well-known problem for many mobile operators that they can lose track of their repeater installations and performance. Some repeaters might actually be installed without their knowledge and a flaw in the repeater or its configuration can have a significant impact on the Donor cell's performance.

A repeater is a set of amplifiers, one amplifier for the uplink, one for the downlink. We know that these internal amplifiers both come with a specific gain and a noise figure. This noise figure will generate noise power that will be broadcast in the service area (inside the building) and noise power transmitted back to the donor cell on the outdoor network. The UL noise power generated by the repeater is typically the main concern and must be evaluated carefully when configuring the UL gain settings in the system, especially when the repeater is connected to an Active DAS where you also need to adjust gain settings (for more detail on noise and noise power calculations refer to Chapter 7), Potentially, the increased noise load in the UL in the Donor cell could cause the UL foot print of the donor cell to shrink losing coverage area on the edge of the cell, an effect as illustrated in Figure 4.35 and Figure 4.36.

For WCDMA/3G solutions we know from Chapters 2 and 10 how important it is to limit the impact of noise on the UL due to the fact that 3G is a noise

[redacted]

[redacted]

[redacted]

sensitive system, and ultimately increases noise on the UL thus decreasing UL capacity.

As illustrated in Figure 4.35, a repeater will generate UL noise that will impact upon the uplink coverage area of the Donor cell. The idle load in the 3G Donor cell could be affected so badly by the noise generated and injected by the repeater that it will offset Admission Control and limit UL capacity (see Chapter 10 for more detail). In practice, you sometimes

Figure 4.35 Noise impact on the UL of the Donor cell, the noise power generated on the UL of the Donor Cell will cause UL cell shrinkage
Donor cell
Figure 4.36 Noise impact of a faulty repeater on the Donor cell and throughout the macro network, if a repeater generates too much UL noise power, a wide spread area of the macro network can be impacted on the UL
have to make your repeater fed DAS uplink limited so as to avoid loading the Donor and other cells with the noise power from the repeater (see Figure 4.36). For indoor DAS where a repeater is feeding an Active DAS - the noise power out of the active DAS will be amplified by the repeater - this will add its own NF to the system and if this is not carefully evaluated when setting the gain in the DAS and on the repeater, the impact of this noise power can cause degradation of UL

[redacted]

[redacted]

capacity in a wide area of the network, as illustrated in Figure 4.36. It might be that a channel selective repeater is used to pick up Cell D (Figure 4.36), but, as illustrated, the UL noise power of the repeater will cause UL shrinkage on Cell A, B, C and E.	[redacted]
It is important to remember that the repeater, depending on type, will cause noise power on adjacent channels and spectrum, which may affect other operator's cells. As a rule of the thumb, one should aim for the repeater system to be designed to keep the noise floor radiated back to the BS receiver at least 6 dB below the BTS receiver's (multi-coupler's) noise floor. In general, we must remember that the purpose of the repeater is to overcome the link loss between the Donor and the repeater. The rise in noise is the noise power of the repeater system (NF + UL + gain of donor antenna and cable system), therefore the noise power generated at the input of the Donor cell would be any excessive gain in margin over the actual link loss.	[redacted]
	[redacted]
Careful consideration is needed if you consider daisy chaining several repeaters, i.e. one repeater repeating the signal from another repeater, no matter if the repeaters are coupled via	[redacted]

the air, or hardwired through cables: you need to be very careful with the potential cascaded noise ramp up (Chapter 7). This would be the case if an off-air repeater is feeding an Active DAS - that in itself could be considered as a repeater system. In practice, it is very important to configure the gain of the UL on the Active DAS that feeds the repeater correctly. If we set the UL gain too high on the active DAS, the noise power injected in the UL of the off-air repeater will be much too high and amplified by the repeater and ultimately injected over the air-link on the base station uplink, limiting the UL capacity/performance of the Donor cell.

DL Power Offset and Power Control

One could argue that repeaters add capacity, to the DL that is - as we have just learned we must configure the repeater system carefully so as not to cannibalize UL capacity.

On the DL, however, the added DL power will free up power from the Donor cell, if the Donor cell was providing coverage in the area where we implement the repeater.

One must be careful when configuring the DL gain and UL gain of the entire system, and strive to keep the balance between UL and DL gain due to Power Control concerns. Depending on the type of system (2G, 3G, 4G, etc) the effect is different - but offsetting the radiated power in the

[redacted]

[redacted]

cell from the broadcast power that is also included in the System Information will impact upon Random Access to the cell during call set-up and power control in general, see Chapter 10 for more detail.

Concerns

When re-radiating a cell inside a building via a DAS feed by a repeater, Diversity and MIMO performance will be impacted (voided). This might also be a concern when evaluating the service requirements. Delays on the RF link must also be considered. One might pick up a distant Donor cell and add delay to the signals due to the repeater and DAS - this will skew the timing of the cell, affect the service range and One might have to widen the search window of the Donor cell. For more detail on delay refer to Chapter 10, and Section 11.12 for an example of how to evaluate the impact of delay caused by repeaters.

Obviously we must also be careful if we rely on very distant donors, and make sure that neighbor cells are defined and updated according to the new service area.

4.9 Repeaters for Rail Solutions

Rail coverage of passenger trains is a priority for many mobile operators, and as the rise in business travel via rail services increases, so does the demand for a good wireless service onboard trains.

[redacted]

However, it is a challenge for mobile operators to provide the sufficient signal and domi-nance needed to maintain high data services inside trains, sometimes even to provide basic voice services. Even if base stations are deployed at frequent intervals along the train line, or if the mobile operator relies on an outdoor DAS along the rail track (for more detail on Outdoor DAS refer to Chapter 12) the problem remains to get sufficient RF penetration through the train in order to service the users inside the train carriage.

Issues with penetration losses arise mainly from the fact that the train itself is a long metal tube, and modern trains even have metallic coating on the windows (see Section 11.2 for more detail).

Often the mobile operator has only one way to solve this issue, and that is to install an on-board repeater on the train that can compensate for the loss in the train.

The next chapter will highlight some of the many issues related to this challenge, of installing a repeater and DAS onboard a train.

4.9.1 Repeater Principle on a Train

Repeaters in general are a challenge, most of the concerns have been covered in the previous chapter, but one must realize that when deploying a mobile repeater solution onboard a train it all becomes even more

[redacted]

complex. The principle of a typical train repeater application can be seen in Figure 4.37; a donor/ pick-up antenna, typically Omni Directional, will link the repeater onboard the train to the Figure 4.37 Repeater deployments on a train; small passive DAS fed by a repeater. Also a mobile Wi-Fi access point is supporting Wi-Fi users inside the train, utilizing mobile data as backhaul outside macro network. One or more service antennas and/or radiating cable inside the train will then connect the users to the outdoor network; normally a radiating cable could be an alternative to the service antennas. Sometimes a mobile wireless Access Point could be deployed in the train carriage. This device provides a Wi-Fi service onboard for data users that do not rely on the direct data service via the mobile network. The mobile Wi-Fi Access Point backhauls the data traffic via the mobile data service provided through the repeater, thus relying on a level of high data service from the mobile ne 4.9.2 Onboard DAS Solutions The rolling stock of a railway operator is a multiple of different sections of trains that some-times operate as small individual trains consisting of two carriages, and sometimes several of these two-section trains connect together and form a single train of four, six, eight or more of these smaller sections.	[redacted] [redacted] [redacted]

Frequency span is also a challenge, for multiband solutions spanning from 800 MHz to 2600 MHz a 1/2 inch radiating cable could be a good alternative - even when installed in a plastic cable tray against a metallic ceiling. However, one always carry out a mock up installation in order to verify the performance in the real life enviroment.	[redacted]
Several Repeaters/DAS on the Same Train	[redacted]
To cope with this mobility challange and the need for adaptability one needs to install a repeater and DAS solution inside every two (or one) carriage. This will make sure that each repeater and DAS system will be operational no matter which configuration the rail operator will use for the train service.	[redacted]
However, this will also mean that sometimes you will have two to eight independent repeaters and DAS systems onboard the same train, operational in the same cell/cells at the same time. This will require careful consideration and also raise some concerns when it comes to radio planning.	[redacted]
Repeater Features for Mobile Rail Deployment	[redacted]
When using repeaters to feed a normal DAS inside a building we can control and measure the signal levels, gain settings, isolation, etc. We can evaluate the impact on the cells from the mobile operator, or operators that feed the signal; this is not that easy	[redacted]

when designing repeaters for rail deployment.	[redacted]
In Section 4.8.2 we evaluated the different repeater types and what type of repeater is most applicable for various deployments. Typically a repeater deployment on a train will be a multi operator solution, so a wide band repeater is required.	[redacted]
However, given the dynamic nature of the radio conditions that will be encountered when feeding a mobile repeater solution, the evaluation of applicable repeaters for mobile rail deployment is much different.	[redacted]
Let us address a few of the main challenges when deploying mobile repeaters onboard a train.	[redacted]
In general, a standard isolation of the gain +10 dB could work, but given the physical proximity of the donor antenna (typically omni directional) cell and the service antennas inside the train, the isolation will often be pretty low, limiting the possible gain. One must also take into consideration the fact that the isolation can vary greatly, due to reflections from objects near to the train; a prime example will be when a train enters a tunnel, then the isolation will plunge - thus limiting performance.	[redacted]
One has actually seen an example of an onboard rail repeater/DAS deployment presented at a conference,	[redacted]

where everything worked perfectly - after some fine tuning of gains, etc. However, the downside was that every time the train doors opened the isolation dropped and the repeater started to feed-back (oscillate) and calls dropped, both inside the train and, even worse, also in the nearby cells due to UL interference in nearby base stations caused by the oscillating repeater!

and Service Levels

Considering the typical repeater deployment, as seen in Figure 4.37, it is evident that the donor signal level feeding the repeater can vary by 80 dB or more, depending on the location of the train, relative to the Donor cells. It is also very easy to appreciate that quite often one operator will have a donor base station a few meters from the train and at the same time other operators will have much more distant Donor cells feeding the same wideband repeater solution and DAS. The difference between these Donor cells could easily be more than 80 dB - and given the limitations in terms of dynamic range and the receiver blocking concerns of the repeater, some automatic functionality is required controlling the gain of the repeater and DAS.

It will never be 100% perfect, and it will always be a compromise, but it is recommended that one use a repeater where one can limit the gain to a pre-set maximum. This pre-set gain will balance out the losses of the train and provide just enough signal inside the

[redacted]

[redacted]

[redacted]

train to maintain service. Then, on top of this pre-set gain, some sort of automatic gain control is desirable to some extent. However, one must realize that when the train is very close to one operator's donor antenna, and far from other operators' antennas, this could mean that the automatic gain control will turn the gain down so low, in order to avoid receiver blocking, that there is not sufficient signal level from the more distant donors. Some manufacturers offer special repeater hardware dedicated for rail deployment, with individual sections of repeaters, one for each of the mobile operators - with adaptive gain for each individual operator. As we know, repeaters will add delay to the signals, like any amplifier, and will skew the timing of the cell service. Normally this will not be a major concern, but one must realize that if one is feeding the repeater with a signal that is radiated by a tunnel DAS or Outdoor DAS where there might already be concerns with the timing offset due to delays of the Donor DAS (see Section 11.11 for more detail) then the extra delay from the on-board repeater could be the final offset that takes the system over the limit. Where repeaters and DAS systems are deployed in rail carriages, just to get access to a faulty unit for repairs is a	[redacted]

concern, and normally this will have to be scheduled for the next time the train is in for service. But how will one actually know that there is a problem? Yes, make sure to use repeaters where one can connect and control alarms and settings, etc., via a wireless modem, and as a minimum have an ‘SMS alarm system’ that will provide you with an SMS with the name/number of the repeater if there is an alarm. There are devices available where you can pre program alarm labels to a range of inputs, and the device will then send an SMS accordingly if the specific input is triggered. Also, make sure that the modem will relay all alarms from the repeater back to the network in the event of a power failure - so that the system will know that one lost power to the system - and did not lose modem functionality. In practice, a short battery backup to the wireless modem should be implemented, and one alarm trigger on the loss of DC power to the repeater system.

GPS Control

Sometimes one might deploy a rail repeater system onboard a train that passes through other countries or regions where it is not desired to have the repeater operational. This could be in an urban area where the signal levels are high enough to service users inside the train without the repeater being activated, and thus also eliminating noise load on the uplink of the macro network. It could also be

[redacted]

[redacted]

the case that the repeater moves into another country where you do not have permission or desire to maintain the service. In these cases you can deploy a repeater that is controlled by GPS location. You can define exactly when and where you want the repeater to be activated. Some solutions even provide an option to use GPS control of the supported bands and services when passing over international borders. Wi-Fi and Data Services With some applications it is desired to provide an onboard Wi-Fi service for data users. Some PCs might not be able to log on directly to the 3G/4G data service, but would have to rely on Wi-Fi. Providing mobile Wi-Fi coverage is possible when using a mobile wireless WLAN Access Point, as shown in Figure 4.37. The Mobile Access Point backhauls the traffic using the EDGE/3G/4G, via the repeater and services the PC users inside the train carriage via Wi-Fi. Naturally the data speed on Wi-Fi depends on the data offerings and quality via the repeater. 4.9.4 Practical Concerns with Repeaters on Rail Given the special nature of the environment of the application when you deploy repeaters onboard trains there are a number of practical concerns that are very important to keep in mind. Equipment Certification	[redacted] [redacted] [redacted]

Most rail operators will demand that ALL the hardware you want to deploy inside and on a train comply with specific standards that apply to equipment that is to be used in railway installations. Obviously there is radio compatibility with other communication systems installed on or in the train, but there are many other concerns: fire safety, CFC free cabling, labeling of all equipment, cables, etc. One example is the donor antenna; one must make sure to use only an approved rail antenna that is designed to withstand that harsh environment on top of a train. One example might be that you fail to realize that an antenna installed on a train must be able to take a hit from one of the electrical power lines that feed the train with power, without endangering any passenger or equipment inside the train!	[redacted]
So be sure to comply with all the appropriate standards, it can be fatal - literally - not to do so. Mechanical Issues Do not underestimate the impact of the mechanical stress on repeater and DAS equipment due to the vibrations and temperature extremes onboard a train.	[redacted]
Installation space is very restricted, but do try to find a location with relative easy access, stable temperature and mount the active repeater and DAS equipment in shock/vibration absorbing brackets.	[redacted]
There are many examples of repeater solutions that virtually fell to pieces	[redacted]

after a few months' operation in a train installation, due to vibration and mechanical stress. So on top of the normal RF testing that one may apply when approving new equipment in your network; be sure to evaluate the mechanical craftsmanship of the repeater and other equipment that is intended to be deployed onboard the train. Also, pay attention to the craftsmanship of the installation work itself, the fixing of cables, antennas, etc.	[redacted] [redacted]
Power Supply The lack of a good quality power supply onboard a train is one of the biggest challenges, when it comes to the reliability of the solution. Make sure that all active equipment can handle the high spikes, dips and general noise that come on the power supply line to the repeater. Conclusion on Repeaters Hopefully this chapter on repeaters and repeater deployment has provided some insight on repeater applications and what to consider when designing these solutions. Repeaters are a strong tool, can be cost efficient and in some cases the only remedy to solve a coverage problem onboard a train or a ship. Repeaters can be an excellent solution to feed an indoor DAS, but it takes skill and careful configuration and planning to maximize performance, and to minimize the impact on the Donor cells. 4.10 Active DAS Data	[redacted]

Active DAS systems consist to a large extent of amplifiers and repeater/BDA systems; therefore it is important for the RF planner to understand the basic data of these system components. Many of these standard metrics are used to benchmark the radio performance of different manufacturers and systems. Make sure that the data you are comparing all use the same standard benchmark reference.

The amplifiers used in active DAS, repeaters and BDAs have to be very linear, in order not to distort the signal and degrade the modulation. The more complex the modulation used, the higher demands are on linearity and performance. This is very important for the higher coding schemes on 2G EDGE, 3G and especially 4G. Be careful when selecting equipment used for indoor DAS systems, since performance of the system is often directly related to the price. The most basic parameters and merits are described in this section.

4.10.1 Gain and Delay Gain

Gain is the amplification of the system (as shown in Figure 4.34), the difference between input signal and output signal power. The power of the output signal is:

output signal = input signal + system gain (dB), or input xgain factor (linear value)

Gain is typically stated in dB. For a system with a factor 2 power gain, for example, 1 W input (+30 dBm) will lead to 2 W output.

[redacted]

[redacted]

Power gain in dB can be calculated as:

Gain (W)= 10 log (gain factor) = 3dB, thus the output power will be +33dBm

For voltage, gain factors can be converted to dB using:
Gain (voltage) = 20 log (gain factor)
Gain can be negative; often it will be referred to as attenuation or loss.

Figure 4.38 Input/output signal of an amplifier vs time
Indoor Radio Plann'
Delay
Delay is the time difference between the input and output signal (as shown in Figure 4.38). In practice this will offset the timing for mobile systems. In 2G the timing advance will be offset (increased), and the synchronization window on the 3G base station network may have to be adjusted wider to accommodate the delay introduced.
Note that you have to include both the delay of the active elements, and the delay of cables (also optical) due to the decreased velocity of the propagation on the cable, for large systems. (See Chapter 11.11 for more details.)
The signal level in RF design is described as absolute power related to 1 mW (in 50 ^) and expressed in dBm.
Power Per Carrier
Amplifiers in active DAS systems, repeaters and BDAs are normally composite amplifiers. This means that

[redacted]

[redacted]

[redacted]

the same amplifier amplifies all carriers throughout the bandwidth. All car-riers share the same amplifier resource; the result of this is that the more carriers the amplifier must support, the less power can be used for each carrier. The sum of all the powers will remain the same, hence the name composite power. Every time you double the number of carriers, the power decreases about 3 dB per carrier, depending on the efficiency of the amplifier. For an example, see Table 4.4. 4.10.3 Bandwidth, Ripple Bandwidth Normally, when defining the bandwidth of an amplifier, it is the 3 dB bandwidth (as shown in Figure 4.39) that is referred to. The 3 dB bandwidth is the band that supports the amplification with a gain decrease of maximum 3 dB. Table 4.4 Power per carrier from an active DAS Number of carriers Power per carrier Gain Ripple Gain ripple describes the variance in gain over the bandwidth (as shown in Figure 4.39). 4.10.4 The 1 dB Compression Point The 1 dB compression point (P1dB) is a measure of amplitude linearity. This figure is used for defining output power capabilities (as shown in Figure 4.40). The gain of an amplifier falls as the output of the amplifier reaches	[redacted] [redacted] [redacted]

saturation; a higher compression point means higher output power. P1dB is at an input (or output) power where the gain of the amplifier is 1dB below the ideal linear gain. P1dB is a convenient point at which to specify the output power rating of an amplifier.

Example

If the output P1dB is +20 dBm, the output power from this amplifier is rated at +20 dBm maximum.

Avoid Intermodulation Problems

Reducing the output power below the pldB reduces distortion. Normally manufacturers back off about 10 dB from the PldB point: an amplifier with 20 dBm PldB is normally used up to +10 dBm.

IP3 is a mathematical term (as shown in Figure 4.41). It is a theoretical input point at which the fundamental (wanted) signal and the third-order distorted (unwanted) signal are equal in level to the ideal linear signal (the lines A and B).

The hypothetical input point is the input IP3 and the output power is the output IP3. IM3 ‘slope’ (B) is three times as steep (in dB) as is the desired fundamental gain slope A.

Unlike the PldB, the IP3 involves two input signals. The PldB and IP3 are closely related: roughly IP3 = PldB + 10dB

Testing IP3

IP3 is used as a merit of linearity or

[redacted]

[redacted]

distortion. Higher IP3 means better linearity and less distortion. The third-order inter-modulation products are the result of inter-mixing the inputs by the nonlinearities in the amplifier: Input power Figure 4.43 Harmonic distortion The two-tone test (as shown in Figure 4.42) is often used to test IP3. Third-order inter-modulation products are important since their frequencies fall close to the wanted signal, making filtering of IM3 an issue.	[redacted]
4.10.6 Harmonic Distortion, Inter-modulation	[redacted]
The harmonic distortion (Figure 4.43) specifies the distortion products created at integers of the fundamental frequency; dBc means dB in relation to the carrier.	[redacted]
4.10.7 Spurious Emissions Spurious emissions (as shown in Figure 4.44) are emissions, which are generated by unwanted transmitter effects such as harmonics emission or inter-modulation products. 4.10.8 Noise Figure The noise figure is the noise factor described in dB, and is the most important figure to note on the uplink of an amplifier system. The NF will affect the DAS sensitivity on the uplink. Indoor Radio Plann Figure 4.44 Spurious emissions from a transmitter	[redacted]

The noise factor (F) is defined as the input signal-to-noise ratio divided by the output signal-to-noise ratio. In other words the noise factor is the amount of noise introduced by the amplifier itself, on top of the input noise.

The effect of noise and noise calculations will be described in more details in Chapter 7.

Failures are a concern when installing distributed active elements in a building. All compo-nents, active or passive, will eventually fail; the trick for the manufacturer is to insure that the expected failure is after the expected operational time of the system (as shown in Figure 4.45). Typically there will be an expected lifetime of a mobile system of l0-l5 years. It makes no sense to design systems that can last for l30 years that are too expensive. Having multiple active elements scattered around a building, can be a service access concern when implementing “full active DAS”.

‘Infant Mortality’

The manufacture will perform a ‘burn-in’ test of the equipment in order to insure that the ‘infant mortality’ is cleared from the shipped equipment.

Operational Period

For an active element, it is assumed that during the useful operating life period the parts have constant failure rates, and equipment failure rates follow an exponential law of

[redacted]

[redacted]

[redacted]

distribution. MTBF of the equipment can be calculated as:

MTBF = l/(sum of all the part failure rates)

i'Infant mortality' ' failures
Operational Wear out failures

Figure 4.45 The MTBF curve - ‘the bathtub curve’ - of distribution of failures Probability of Failures

The probability that the equipment will be operational for some time T without failure is given by:

Thus, for a product with an MTBF of 450 000 h, and an operating time of interest of 7 years (61320 h):

There is an 87.3% probability that the system will operate for the 7 years without a failure, or that 87.3% of the units in the field will still be working after 7 years.

This is a useful guideline to estimate number of spares needed for your installed base of equipment.

4.10.10 Dynamic Range and Near-far Effect

When designing indoor DAS it is important to realize that the amplifiers in remote units, repeaters and front end of base stations have their limitations. Normally we are concerned with the sensitivity in the low end of the RF level range; however, often the higher signals pose more of a challenge when designing and implementing indoor DAS, due to the close proximity of the mobiles to the DAS antennas. Take especially care when implementing “wideband” DAS solutions. Then the UL can be “hit” by terminals not in service and

[redacted]

[redacted]

[redacted]

[redacted]

thus in power control by the DAS.

Let us look at the two most important parameters; receiver dynamic range and receiver blocking.

Indoor Radio Plann'

Receiver Dynamic Range

Receiver dynamic range is the ability of a receiver to detect a low signal without degradation of the quality while a strong signal is present at the same time. This is a very important parameter to consider when evaluating the active parts of a DAS, a repeater, the base station, etc. One could say that the dynamic range of receiver is the range/span of signal levels, low to high, over which it can operate without compromising the quality of the detected signals. The low end of this range is determined by receiver sensitivity, dictated by the noise figure of the receiver and the high end is determined by its ability to withstand overload and distortion with strong signals present at the input at the receiver; this is determined by the receiver’s IP3 (see Section 4.12.5).

So, in short, the dynamic range of a receiver (the uplink in the remote unit or in the input of the repeater) is essentially the range of signal levels from low to high over which it can operate without problems.

Receiver Blocking

The presence of strong RF signals could be ‘in-band signals’, i.e. signals within the bandwidth support of the DAS/base station, not necessarily at the operational spectrum of that

[redacted]

[redacted]

particular operator, and could lead to distortion and blocking of the receive path of the DAS/base station, affecting performance of the receiver - especially for lower power signals. The ability of the active components in the DAS to cope with high signals without blocking is an important parameter to look out for, and this is one of the parameters that distinguishes a good quality active DAS/repeater from another - so it is important that a receiver stays within its linear operational range in order not to create any intermodulation distortion at high signal levels; a high IP3 is therefore important (see Section 4.l2.5).

[redacted]

Some active DAS has an integrated limiter (ALC, Automatic Level Control) integrated in the remote unit, that will limit the signal feed internally to the amplifier in the uplink. The ALC will kick in before the receiver starts generating intermodulation - this function also applies to many repeater solutions; however, it is important to confirm that this ALC is actually effective prior to the first amplifier stage - if not, it is of little use, if the first stage of the amplifier is already generating intermodulation.

[redacted]

Let us have a look at a real life example in Figure 4.46, considering three different sce-narios. This is a typical office building with a central Omni directional antenna on the floor serviced by mobile operator A; three mobiles are currently active on this

[redacted]

floor; MSl, MS2 and MS3. There is also a macro cell present at the floor serviced by Operator B.

Scenario 1 - All Mobiles in the Indoor Cell, in Power Control

In this scenario (Figure 4.46 and Figure 4.47), all three mobiles; MSl, MS2 and MS3, are in traffic mode, all camped on the indoor cell serviced by mobile Operator A. Thanks to Power Control the system ensures that the receive level on the uplink of the base station is kept at a relatively constant level (Figure 4.47). In this example the target signal level is -80 dBm. This is very important in WCDMA/3G where the power from all mobiles should be kept at the

Figure 4.46 Three mobiles in a typical indoor environment with a centrally placed Omni directional antenna connected to an indoor DAS that services Operator A, and one outdoor cell also providing service from Operator B

same level, due to the fact that all cells and mobiles are on the same RF channel, so one mobile could easily degrade the performance of the whole system, cause intermodulation in the receiver, possibly receiver blocking, and thus even cause dropped calls (Scenario 2). Thanks to uplink power control this is avoided. However, there is a limit to power control - even at the lowest possible mobile transmit power, a mobile that is very close to the indoor DAS antenna could cause

[redacted]

[redacted]

concern and potential problems - therefore mobile systems specify a MCL
(Minimum Coupling Loss). The MCL is, as the name suggests, the lowest allowable path loss between the base station and the mobile that the system can handle without any problems even with the lowest possible transmit power from the mobile.

Scenario 2 - All Mobiles in the Indoor Cell, No Power Control

This is the same situation as Scenario 1, all three mobiles, MS1, MS2 and MS3, are in traffic mode all camped in the indoor cell serviced by mobile Operator A (Figure 4.46 and Figure 4.47). In this scenario there is no Power Control active - this will mean the all three mobiles are at maximum transmit power. The different path loss due to distance and wall attenuation (for MS3) causes a big offset in uplink receive power at the indoor base station, as illustrated in Figure 4.47. For a WCDM/3G system this is devastating - MS1 will simply block out the signal for all other mobiles in the cell; MS2 and MS3 will simply drop their calls
- however, in real life this is avoided thanks to Power Control. However, all mobiles might not be in Power Control by the indoor cell (Scenario 3).

[redacted]

Scenario 3 - One Mobile not in Power Control In this scenario (Figure 4.46 and Figure 4.47), MS2 and MS3 are in traffic mode all connected to the indoor cell service by mobile Operator A. These two mobiles are in power control, hence the uplink signal levels of the base station are at the desired, controlled uplink signal level. However, in this scenario mobile MS1 is camped in the outdoor cell from Operator B. This is a concern, MS1 is blasting out full transmit power in order to compensate for the increased path loss to the outdoor base station from Operator B (Figure 4.46). Even though MS3 is operating on a different frequency, the fact is that it is still in the supported frequency range of both the indoor DAS and the bandwidth of the base station receiver, and the uplink amplifier of the remote unit connected to the indoor Omni antenna. Therefore it is very likely that with the mobile blasting full power to reach the outdoor network, MS3 can cause receiver blocking or adjacent channel interference; see Section 5.9.2 for more detail about ACIR (Adjacent Channel Interference Ratio). Try to Avoid the Potential Problems	[redacted]
The problems with the 'near-far' effect and receiver blocking can be avoided if one makes sure to keep safe from the MCL; in reality one should strive to be sure not to place indoor antennas where the users can get very	[redacted]

close to the antenna. In practice this is a challenge due to physical limitations - but try at least to keep the antennas distant (a few meters) from locations where users are stationary. In extreme cases one might need to add extra loss between the indoor antenna and the active element, remote unit, repeater or base station, to avoid these problems. These problems are yet another reason as to why we should consider multi operator solutions inside buildings (see Section 5.10). The increased complexity of several technologies (2G, 3G, 4G, TDD/FDD) deployed in spectra with close RF frequency proximity, makes this challenge even harder - and giving careful attention to these potential problems is important.	[redacted]
EMR is a concern for mobile users all over the world. From time to time there are heated debates in the media, but indoor radio planners need to stand above these often emotional discussions and try to be neutral and objective. Above all, you need to accept and respect that this is in fact a concern for the users, however unlikely you yourself believe the danger to. You need to comply with any given EMR standards and guidelines that apply in the region you work in and make sure that the indoor DAS systems you design and implement fulfill the approved regulations in the country where the	[redacted]

systems are implemented. Often you will have to accept that a neutral party conducts post-implementation on-site measurements in the building, and certifies that the design is within the applicable EMR specification. Different regions around the world use different standards and regulations, and these regulations change over time. Find out exactly what standard applies within your country. Currently many countries use the guideline laid down by the ICNIRP (International Commission on Non-ionizing Radiation Protection), who are recognized by WHO. This guideline specifies the maximum allowed EMR exposure for the general public 24 h/7 days/52 weeks of the year (higher levels are allowed for professional users, some regions of the world uses lower values). A measurement specification (EN50382) specifies how these measurements should be conducted and that a mobile transmitter must radiate lower than: • 900 MHz, maximum 4.5 W/m2. • 1800 MHz, maximum 9 W/m2. • 2100 MHz, maximum 10 W/m2. The measurement should be averaged over 6 min. Guidelines are different for different countries, and will be adjusted over time. Check exactly what applies in	[redacted]

your case; some countries apply a standard that is much stricter than the ICNIRP levels.

You cannot relate these values to a specific receiver level in dBm, due to the fact that the ICNIRP levels are power density, and therefore will be the sum of all powers on air within the measured spectrum. Measuring in dBm using a test mobile receiver will only indicate the specific level for that one carrier you are measuring, not the sum of power from all carriers.

Example

This is an example of a measurement at a real-life installation of a DAS, using 2G 1800 MHz 18 dBm radiated from the omni DAS antenna, four TRX with full load:

50 cm distance from the antenna: 0.630W/m2 (average over 6 min) 200cm distance from the antenna: 0.0067W/m2 (average over 6min)

The measurement clearly shows that, in practice, you are well below the maximum allowed ICNIRP levels.

DAS Systems are Normally Well Below These Levels

Typical DAS systems, passive or active, are well below these levels. However, I have seen examples of high-gain outdoor sector antennas, connected directly indoors to a high-power base station, and users able get so close that they can touch the antenna! This is clearly not a correct design; this ‘hot’ antenna might blast away, providing a lot of coverage in the nearby indoor area, and most

[redacted]

[redacted]

likely leaking out interference outside the building. In this extreme case you could exceed the limits. However, common sense must be applied both with regards to good indoor radio planning and for minimizing EMR from the indoor DAS. When you are being questioned by the users in the building whether it will be safe to work every day underneath the installed indoor DAS antenna, you should always ask yourself the question whether you would want to sit underneath that antenna 24/7 and design accordingly. Is it Safe? Well that is the question; the current EMR guidelines are defined with a large margin to any level that might cause any known effect on humans. Often you will be asked if you can prove that these EMR levels are safe. This is an understandable question to ask, but science cannot prove a noneffect, only an effect, and until now no effect has ever been documented when adhering to these guidelines for the design levels. To use an analogy, we cannot prove it is safe to drink a glass of milk each day for 50 years! Still we drink milk every day. We might be able to prove that milk was hazardous, if we could conclude an effect due to a level of toxin found in the milk, but with no toxin found, there is nothing we can do but to accept that it is most likely	[redacted] [redacted] [redacted]

safe to drink milk. We do have a respon- cibility to always assure a respectfull dialouge on these sensitive subjects.	[redacted]
Most users inside buildings are concerned about the radiation from the DAS antenna, but it is a fact that the main source of human EMR when using mobile phones is not the indoor DAS antennas, but the mobile handset. This is due to the proximity of the handset to the mobile user. Even if a high-power outdoor base station may generate 700 W and the mobile only 2 W, the determining parameter is the distance to the antenna. Having the mobile close to the user’s head will expose the user to more power than would an outdoor base station even as close as 50 m! Indoors the margin is even clearer as shown by the measurement just documented in the example above.	[redacted]
It is a fact that the main source for EMR exposure is the mobile, and the trick is to keep the mobile at the lowest possible transmit power. This is the only way to minimize the exposure of users inside the building. The power control function in the mobile network will adjust the transmit power from the mobile automatically, in order to insure that the received signal level on the uplink at the base station is within the preset level window for minimum and	[redacted]

maximum receive levels.

This power control insures that the more attenuation there is on the radio link (buildings, walls etc.) and distance between the mobile and the base station, the higher transmit power the mobile will use to compensate for this loss. Therefore the only way to minimize the EMR

exposure is to make sure to keep the attenuation on the link as low as possible. The more indoor antennas you have in the building, the lower the link attenuation is to the users and the lower transmit power indoor users will be exposed to.

Indoor DAS will Provide Lower EMR Levels

The effect is that, even in buildings very close to an outdoor base station, and where the mobile coverage seems perfect, the mobile will typically operate at or close to the full transmit power. The high downlink power from the base station might provide high signal levels received by the mobile, but the power control depends on the uplink level at the base station, and the mobile transmits at far lower levels than the high power transmitter at the base station.

Indoor antenna systems with low attenuation will help. By deploying an indoor DAS you can create lower path loss for the mobile to the base station, and the mobile will operate on lower transmit power.

Less Radiation with Active DAS

[redacted]

[redacted]

Installing a passive DAS inside a building will to some extent bring down the mobile transmit power, but it is a fact that the mobile still needs to overcome the attenuation of the passive DAS, thus operating on a relatively high power even on an indoor system close to the DAS antenna. The mobile transmit power obviously depends on the attenuation of the passive DAS, but with 20 dB of attenuation on the passive DAS, the mobile has to transmit 20 dB higher power compared with the active DAS from Section 4.4.2.	[redacted]
By deploying an active DAS inside buildings, the attenuation between the mobiles and the indoor antennas is low. The result is that the mobile will run at or close to minimum transmit power. This is due to the active DAS being a 'zero loss' system; it is an active system where all the losses in cables are compensated by small amplifiers close to the antennas. This only applies to pure active DAS; using hybrid DAS the mobile will still have to compensate for the passive losses prior to the HRU (as shown in Figure 4.18).	[redacted]
Note that power control is triggered by the received level, and the noise figure of the active DAS will not cause the transmit power from the mobile to be adjusted up.	[redacted]
Example, Lower Mobile Transmit Power with Active DAS The low mobile transmit power, using	[redacted]

an active DAS system, is evident in this graph (as shown in Figure 4.48). The graph shows the typical mobile transmit power inside an office environment vs the distance to the indoor DAS antenna. This is a 2G-1800 example, where the minimum received level on the base station is set to -75 dBm, so the base station will adjust the transmit power of the mobile in order to reach this uplink level.	[redacted]
On the graph (as shown in Figure 4.48), the pure active system is compared with typical passive systems with 20, 30 and 40 dB of attenuation from the base station to the DAS antenna.	[redacted]
As shown, the transmit power from the mobile covered by a passive DAS will only use the lowest power level when it is located very close to the antennas, whereas the same mobile in the same type of environment on an active DAS will stay on the lowest possible transmit power even up to a distance of 19 m from the indoor antenna, and stay at a low level compared with the passive DAS.	[redacted]
The mobile connected to the passive DAS will ramp up transmit power even close to the DAS antenna, and this is due to the passive attenuation. This is evident on the graph, even for the ‘low loss’ 20 dB attenuation of passive DAS. 4.12 Conclusion It is evident that the mobile connected to the pure active system consistently	[redacted]

maintains an output power below 0.01 W, and the mobile connected to a passive system can easily reach 1 or even 2 W (as shown in Figure 4.48). Using a traditional passive distributed antenna system will to some extent help with radiation from mobiles, especially mobiles being serviced by antennas with relatively low loss, close to the base station room. However, the fact is that, due to the losses in the passive system, the mobile has to compensate for the losses in the passive cable dB for dB, resulting in higher transmit power from the mobile and thus higher EMR exposure of the users.	[redacted]
Even if you often need to install an uplink attenuator between the active DAS and the base station to minimize the noise load of the base station, it is clear that the active DAS will keep radiation from the mobiles to the lowest possible power.	[redacted]
Both passive and active DAS will help bring down the transmit power from the mobiles, if the alternative is to rely on coverage via the outdoor macro net. All mobiles have to apply a certain radiation limit (SAR value), so even when operating on the highest power level, no mobile is dangerous.	[redacted]