

DeltaNode Solutions

Fiber-DAS MANUAL



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System Part Number Explanation

Optical Split		CWDM				FOR 3 Band 1		Wavelength FOR 3		Wavelength FOR 2		FOR 1 Band 2		FOR 1 Band 1		Wavelength FOR 1		WDM		Connectors		Voltage		Duplexed		Frequency		Duplexed		Frequency		Duplexed		Frequency		Number of Bands		Sub-family		Product Family	
S	C	B	U	W	-	3	H	C	3	C	2	1	2	1	B	-	W	D	A	-	0	C	0	-	0	G	0	C	0	G	4	R	D	D							

Family:

DDU - 46dBm full band

DDZ - 47dBm single Carrier

DDH - 43dBm full band

DDS - 41dBm single Carrier

DDR - 33dBm full band

DDX - Mixed power levels

of Bands:

1

2

3

4

Frequency:

R - FM Radio

V - VHF (136-174)

T - Tetra (380-400)

M - Gov (406-420)

B - Tetra (410-430)

U - UHF (450-470)

Q - 500MHz T-Band (470-512)

L - Lower 700

H - Higher 700

G - 700 Full band

F - PS 700 - (793-805)

S - 800 SMR

C - Cell 850

N - 900

D - DCS (1800)

P - PCS

I - IMT (1900/2100)

A - AWS (1700/2100)

E - IMT-E (2600)

J - DD 800

Duplexed or DDX Pwr Lvl:

0 - Non-duplexed

1 - Duplexed

For DDX use:

For DDX Pwr Lvl 0 - 9:

0 - Non-duplexed (DDU)

1 - Duplexed (DDU)

2 - Non-duplexed (DDZ)

3 - Duplexed (DDZ)

4 - Non-duplexed (DDH)

5 - Duplexed (DDH)

6 - Non-duplexed (DDS)

7 - Duplexed (DDS)

8 - Non-duplexed (DDR)

9 - Duplexed (DDR)

Voltage:

A - Universal AC (86-264 AC/DC)

D - 48V DC

Connectors:

N - N Connectors

D - 7/16 DIN

M - Mini DIN

WDM:

W - Duplexed - UL and DL on same fiber

wavelength of Uplink: (FOR2 and FOR3 are optional to support multiple Fiber links)

A - 1270

B - 1290

C - 1310 (default C if omitted)

D - 1330

E - 1350

F - 1370

G - 1390

H - 1410

I - 1430

J - 1450

K - 1470

L - 1490

M - 1510

N - 1530

O - 1550

P - 1570

FOR Bands: (if omitted then all bands on one FOR)

Bands for that fiber link (in order as appear in model #) - ie. C123 would be standard FOI driving bands 1,2,3

1

2

3

4

CWDM (option)

WUxxxx - combine multiple Uplink fiber interfaces onto one fiber - each x denotes a wavelength (absence of xxxx implies all UL wavelengths)

WDxxxx - split to multiple Downlink fiber interfaces from one fiber - each x denotes a wavelength (absence of xxxx implies all DL wavelengths)

Optical Split (option)

Sx - Split the fiber at entry - to daisy chain other remotes - x is dB split (3dB equal split if absent)

Examples:

DDR4-GC0-PA1-AD

4 band, 33dBm power output per band, Full band 700 combined with Cell 850 non duplexed, PCS combined with AWS duplexed, AC powered, 7/16 DIN, 1310nm uplink

DDR4-GC0-PA1-AD-B12-C34-WUBCS

4 band, 33dBm power output per band, Full band 700 combined with Cell 850 non duplexed, PCS combined with AWS duplexed, AC powered, 7/16 DIN, Bands 1 and 2 (700 and 850) 1290nm uplink, Bands 2 and 3 (PCS & AWS) 1310nm uplink, CWDM, fiber split (3dB) for daisy chained remotes

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1 Introduction

This manual contains both guidelines on how to design a system using the DeltaNode Fiber-DAS concept and how to install, commission and maintain such a system for the life span of the entire installation. It will also contain many bits of information regarding general practices in the industry as well as other information.

The information in this manual has been proof-read by several people at DeltaNode and industry experts, however we cannot guarantee that there are no errors, omissions or other mistakes. If you should have any questions on the contents in this manual please contact info@deltanode.com or your closest representative for more information on this.

When other manufacturers have converted off-air repeaters into fiber-fed repeaters, DeltaNode has developed the concept from scratch with fiber distribution in mind from the start. This allows for extremely good radio performance and we are proud of the best in class noise figure of less than 3 dB for the whole system, remote unit antenna port to base station interface port.

The Fiber-DAS from DeltaNode is also extremely flexible in its solution meaning that the system can be tailored for almost any needs that should arise. Because of the flexibility there are also many parameters that can be changed by the user. This manual attempts to explain not only what they do, but also how you should reason when you set them up properly.

Together with this manual you should have the aid of the Fiber-DAS calculator, this is an Excel spreadsheet that allows you to simulate the noise figure, intermodulation performance and the system dynamics that will give you a measure on how well the system will perform.

- ✓ *System Noise Figure calculator*
- ✓ *Intermodulation performance calculator*
- ✓ *Uplink / Downlink Balance*
- ✓ *Dynamic headroom indicator*

There is also a system design chapter that contains many useful advices on how to design a well working system as well as some examples on common types of designs where the manual attempts to take you through the design phase step by step.

The installation and commissioning parts of the manual aims at being a good help in the field by providing practical advice on how to counter common problems and how to check that the previously made design is sound.

1.1 Definitions

Here is a list of the abbreviations, industry standard lingo and acronyms used in this document. It is supposed to be a help for the reader and a reference section.

BGW	Base station Gateway
BIU	Base station interface. Also known as the DIU. It is the electrical interface between the Master Unit (MU) and the operator radio base station or another source for the radio signals, such as a off-air repeater.
BTS	See RBS.
DAS	A distributed antenna system. Several antennas connected together in a coaxial network so that several antennas can be fed a signal from a central location.
DL	See “Downlink”
Downlink	The signals that are transmitted from a base station towards a terminal (phone).
Fiber	In this document it refers to the telecommunication fibers used to transmit modulated light as pulses or analogue variations on a glass fiber. The DeltaNode Fiber-DAS system should use single-mode fiber always.
Fiber-DAS	A general name for distribution systems using radio frequency on fiber (RF on Fiber) technology. DAS means “Distributed Antenna System” which refers to the practice of building “spreading nets” with coaxial cables, splitters and antennas to cover larger structures.
FOI	Fiber-optic interface. Also known as DOI (DeltaNode Optical Interface)
FOR	Fiber-optic remote interface, part of the Remote Unit connecting to the fiber.
GSM	Global System for Mobile Communications
iDEN	Integrated Digital Enhanced Network
LTE	Long Term Evolution
MU	Master Unit. This is a rack that contains all the modules that builds up to the head end in the system. This is where the radio base stations interface to the Fiber-DAS system. This is also where the downlink signals from the base stations are converted into laser light and sent over the fiber-optics to the Remote Unit (RU) and the uplink signals from the RU are converted to radio frequency signals and transmitted to the radio base station (RBS, BTS).
POI	Point of Interconnect, RF splitter/combiner unit
QMA	Type of RF Connector. Quick disconnect version of SMA RF Connectors. See SMA
RBS	Radio Base Station. The infrastructure unit normally connected to the antennas in the radio access network (RAN) and sometimes called just Base Station or Base Transceiver Station (BTS).
RGW	Remote Gateway Unit
RU	Remote Unit. This is the the unit closest to the antenna that converts the downlink signal from the fiber to radio frequencies and distributes it over the antenna system. In the reverse, the uplink radio frequencies are converted to modulated laser light and transmitted back to the Master Unit (MU).
SC-APC	The type of connector used for all DeltaNode optical equipment. It is recommended that all connectors between the MU and the RU are of this type. SC-AP can also be accepted in patch panels. All connectors MUST BE ANGLED to avoid signal reflections that are detrimental to the signal quality. Fibers need to be of single-mode type.

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Single mode fiber	A fiber where the light at a specified range of wavelengths only have a single path through. This is required for analogue modulated systems such as the DeltaNode Fiber-DAS system
SMA	SubMiniature version A. A Type of RF Connector.
Switch	A network switch is a computer networking device that connects devices together on a computer network.
TETRA	Terrestrial Trunked Radio. TETRA uses Time Division Multiple Access (TDMA) with four user channels on one radio carrier and 25 kHz spacing between carriers.
UL	See "Uplink"
UMTS	Universal Mobile Telecommunications System is a system where broadband signaling and packetized data are used. The standards are handled in the 3GPP group and the most common type of modulation is WCDMA.
Uplink	The signals that are transmitted from the terminal (phone) towards the base station.
SC-PC	A type of fiber-optic connector which is not angled and should not be used with DeltaNode Fiber-DAS
SC-UPC	Ultra-polished fiber-optic connector. Not recommended with Deltanode Fiber-DAS
RF	Radio Frequencies, denominates the range of transversal electromagnetic waves with a frequency from 3 kHz to 300 GHz. The upper end of the spectrum is often referred to as microwave frequencies.
WCDMA W-CDMA	Wideband Code Division Multiple Access is a technology employed by base station manufacturers who make UMTS base stations. This technology is commonly used in 3G networks and the main modulation employed in Europe.

1.2 RF on fiber

A fiber distributed antenna system (Fiber-DAS) is a very efficient way of transmitting radio signals over large distances. Up to about 25 km of fiber between the head-end and the remote unit is allowed, providing that the radio access technology (RAN) do not suffer timing issues and that the fiber loss is within the specification.

The main principle is to use an infra-red light source which is modulated with the combined radio signals that needs to be propagated. The fiber channel system is ultra wide-band, ranging from 88 MHz up to 2600 MHz and thus covering most types of radio communication systems such as FM broadcast, VHF communication radios, TETRA, GSM, CDMA, WCDMA and other radio access technologies that are available.

The dynamic of the fiber is good enough to tolerate multi-carrier, multi-band and multi-operator solutions this way, but of course they all share the available dynamics and if there are a very large number of carriers the fiber attenuation needs to be looked at of course.

Because most land mobile radio systems and cellular systems are using Frequency Division Duplex (FDD) this means that there needs to be either two separate fibers, one for the uplink (signals from the terminal towards the base station) and for the downlink (signals from the radio base station towards the terminal) or they may be multiplexed on the same fiber using different wavelengths.

The most popular way is to use wave-length division multiplexing (WDM) which is the normal configuration of the DeltaNode Fiber-DAS concept. However, separate UL/DL fibers can be used if it is necessary or desired.

- ✓ *Single mode fiber*
- ✓ *Angled connectors*
- ✓ *Optical loss < 15 dB*

Because the modulation is analogue the system requires the fibers to be of single mode type. All connectors used in DeltaNode equipment for Fiber-DAS are of SC-APC type with a 7° angle. It is very important that all connectors in patches et cetera between the Master Unit (MU) and the Remote Unit (RU) are angled, otherwise reflections are caused which will cause problems with the quality of the signals through the system.

2 System Description

The Fiber-DAS system consists of two major parts. This is the Master Unit (MU) and one or more Remote Units (RU) connected to the Master Unit via optical fibers. Each Remote Unit needs to be connected to a fiber, but up to four RU:s can share a single fiber link using optical splitters.

2.1 Master Unit

The Master Unit consists of a 19 inch frame rack with modules that are selected depending on the system design. Generally all Master Units contains a power supply, at least one Base Station Interface Unit (BIU), an RF splitter/combiner unit called the Point of Interconnect (POI) and minimum one Fiber-Optic Interface card (FOI).

The master unit will also contain a network switch for connecting the communications paths between the modules together and also some kind of gateway, either the Remote Gateway Unit (RGW) or the Base Station Gateway Unit (BGW). The RGW is a smaller compact embedded solution while the BGW is a full featured Linux server that can be set up in many different ways.

The master unit will assign IP addresses to all the subunits in the rack and also for the Remote Units when they are connected to the system via the built in DHCP server present in the RGW and BGW modules. This will configure itself automatically and create a protected sub-net for the system itself that should not be connected directly to a LAN.

For supervision by remote a gateway of the type RGW or BGW is installed. This acts as a firewall and will make sure that the internal traffic in the system stays internal and that the web interface for monitoring and supervision as well as SNMP trap forward is handled as expected.

Each of the modules will be described in the following sections.

2.1.1 MFU – Master Frame Unit

The Master Frame Unit houses the other modules such as power supplies, fiber-optic interface cards and base station interface units.



Figure 1: Master Unit

The frame in the picture shows a frame equipped with 3 base station interface units, 6 fiber-optic interface cards and one power supply.

Functional description

One frame supports several modules which can be placed anywhere in the frame as well as a combination of several different types of units in a frame. There are 16U positions in the frame that can be utilized. The modules have different widths which can be found in each module's specifications in the following sections of this manual.

This means that one shelf can house up to 4 power supplies or 8 base station interface cards or up to 16 fiber-optic interface cards. Each frame needs at least one power supply, but they do not necessarily have to be placed in the frame that they power. Quite often a system has more than one power supply and they are usually placed together in one frame for easy access.

Each frame has two molex connectors that can be connected to a power supply. This allows for a primary and a redundant power supply to be connected to it to ensure operation even if one power supply should fail.

The frame also contains fans used to ventilate the units housed in the frame. These are high quality fans that have a high MTBF.

Specifications

Parameter			
Input voltage		28	VDC
Power connector	Molex	10	Pin
Ethernet connector		RJ45	
Weight (without modules)		2,5	kg
Temperature range	Operational	0-45	°C
Width	16U	19	Inch
Height		3	U
Depth		300	Mm
Maximum number of modules supported	PSU	4	Pcs
	BIU	8	Pcs
	FOI	16	Pcs
Temperature range		0-45	°C

2.1.2 BIU – The Base Station Interface

The BIU is the interface between the operator's base station and the Fiber-DAS system. This module has several RF connectors on the front panel and it contains duplex filters (optional) or separate uplink/downlink paths which can be chosen depending on the needs for the connection to the base station. In most cases the duplexed version with a combined DL/UL port is used.

Functional description

In the duplexed version there are UL test connectors present (SMA) that can be used to monitor the signal out from the BIU. The version without duplex filters has the test connectors replaced by UL connectors and the normally combined DL/UL connectors are replaced by DL only connectors.



Figure 2: Base station interface

There are two separate RF ports in the BIU and the BIU needs to be ordered for the specific frequency bands it will serve. The two paths in the BIU cannot have different frequencies; a GSM 900 BIU will have two GSM 900 paths and cannot be combined with e.g. an 1800 path, this requires a second BIU card to be inserted.

The BIU have four QMA ports that is normally used to connect it to the POI. There are two uplink (input) ports and two downlink (output, Tx) ports. These two are separate port, the isolation between DL 1 and DL 2 is > 50 dB and so is the isolation between the UL 1 and UL 2 ports.

The ports towards the RBS are of SMA female type and the ports towards the POI are of QMA female type. RF patch cables are used to patch the DL and UL paths to the right place in the POI.

There is also an alarm port of the BIU which in the future can be used to connect external alarms but for the time being is not in use. This is a DB9 female connector.

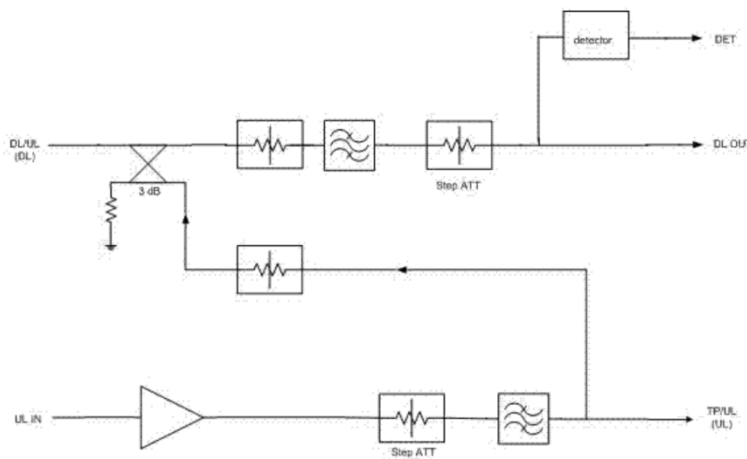
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The BIU is technology neutral and in the downlink path contains only settable attenuators that can be used to adjust the signal strength to proper levels before feeding them into the POI. In the uplink there is an amplifier followed by a settable attenuator used to adjust the signal and the noise level into the base station uplink.

All connections necessary are made from the front of the BIU itself. The maximum recommended input power to the BIU is 30 dBm and there are high power alarms that activate at > 30 dBm and low power alarms at < 10 dBm input power. A higher input power than the recommended can cause the unit to fail permanently thus needing replacement. It is therefore recommended that for high power base station an attenuator is used to ensure that the input power to the BIU can never exceed specifications.

There is also a 0 dBm input version of the BIU available on request.

Schematic of BIU RF paths



The schematic to the left shows the blocks in the BIU for one of the channels and how the signal detector for the downlink level alarms are connected.

Standard variants of the BIU

ArtNo	Configuration	UL MHz	DL MHz	BTS I/F
DBI303	2 x TETRA 390 MHz*	380-385	390-395	Duplex
DBI307	2 x 700 MHz ABC-band	698-716	728-746	Duplex
DBI308S	2 x SMR 800	806-825	851-870	Duplex
DBI308	2 x 850 MHz	824-849	869-894	Duplex
DBI309	2 x 900 MHz	880-915	925-960	Duplex
DBI318	2 x 1800 MHz	1710-1785	1805-1880	Duplex
DBI319	2 x 1900 MHz	1850-1910	1930-1990	Duplex
DBI320	2 x UMTS 2100 MHz	1920-1980	2110-2170	Duplex
DBI321	2 x AWS 2100 MHz	1710-1755	2110-2155	Duplex

Table 1: BIU Variants

*) Several options exists for 5 MHz standard bands for TETRA.

The table above lists standard cellular BIU:s. Other configurations are available upon request as well as units without internal duplex filtering.

RF and electrical performance of the BIU

Parameter		Value	Unit
Downlink attenuation	Settable	10-30 ± 3	dB
Uplink Gain for modules < 1000 MHz	Settable	10 to 20 ± 3	dB
Uplink Gain for modules > 1000 MHz	Settable	-10 to 10 ± 3	dB
IM3 performance		> 55	dB
Max input non-destructive		> 36	dBm
High input alarm threshold level		33	dBm
Low input alarm threshold level		10	dBm
Input return loss		> 20	dB
Impedance for all RF ports		50	Ω
Isolation between ports		> 60	dB
Power consumption		< 15	W
Temperature range		0-45	°C

Table 2: BIU Performance parameters

BIU mechanical specifications

Parameter		
Base station RF ports	SMA	Female
Test ports uplink (if present)	SMA	Female
Interconnecting RF ports to POI	QMA	Female
Alarm connector	DB9	Female
Width	Rack units	2U
Height	Rack units	3U

Table 3: BIU interface specification

LED behavior

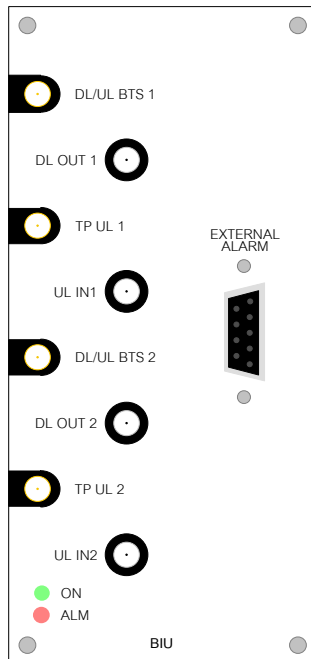
The unit has two LEDs located on the front panel. One is the power on LED (green) and the other is the alarm LED (red). Both LEDs can indicate a number of states by different flashing behaviors.

In an error state the web interface should be used to check the actual condition of the BIU but the LEDs on the front can give you a quick indication on the state of the unit. It is also useful for locating the physical unit if you have several BIUs installed in the same rack.

State	ON LED	ALARM LED	Note
Booting	2 Hz	Off	Normal boot
Booting standalone mode	2 Hz	2 Hz	Not attached to rack
Booting read of MAC address failed	2 Hz	On	Error
Starting	0,1 Hz 90%	0,1 Hz 90%	Kernel startup
Operation	0,5 Hz 10%	Off	Normal operation
Operation	0,5 Hz 10%	1 Hz 10%	Minor alarm state
Operation	0,5 Hz 10%	2 Hz 25%	Major alarm state
Operation	0,5 Hz 10%	On	Critical alarm state

Table 4: LED behaviour of BIU

Interfaces of the BIU



DL/UL BTS 1 / 2

This is RF path where the radio base station is connected to the BIU. Do not exceed the power rating in the downlink for the port.

TP UL 1/2

This is a test port for the uplink. It show the uplink signal in the DL/UL BTS port - 6 dB. This port is replaced by the UL port on a non-duplexed version of the BIU.

DL OUT 1/2

These are the output ports for the downlink signals after they have been treated in the BIU with attenuators and filters.

UL IN 1/2

Here is where the uplinks are connected in to the BIU which will then amplify and/or attenuate as appropriate.

EXTERNAL ALARMS

Will be used for external alarm monitoring in the future.

ON/ALM LED

The LEDs indicates various states as shown in the table above.

2.1.3 POI – The Point of Interconnect

Basically this is a 1U high unit that contains 4 1:8 splitters and some attenuators. This is a coupling field used to tie together the signals between the BIUs and the FOIs in a multiple band or multiple operator system.



Each of the 4 fields has a COMMON port and ports 1-8. If you are using it as a combiner then you should connect the signals you want to combine to the ports 1-8 and you will receive the sum of the signals (minus insertion loss) on the COMMON port.

Using it as a splitter means you connect the combined signal to the COMMON port and you can then receive 8 ports with equal signal strengths on ports 1-8 (minus insertion loss).

RF Performance

Parameter		Value	Unit
Insertion loss COMMON to any port 1:8	Nominal	35	dB
IM3 performance		> 50	dB
Return loss performance		> 20	dB
Maximum signal input level		20	dBm
Isolation between ports in same strip		> 15	dB
Isolation between ports in different strips		> 60	dB

Table 5: Specification of the POI

2.1.4 FOI – The Fiber Optic Interface unit

The FOI is the unit responsible for converting the RF signals in the downlink to fiber-optical laser that can be transmitted on the fiber to the remote. It is also responsible for receiving the laser light transmitted by the Remote Unit and convert it back to RF signals that will then usually go into the POI and then later in to the BIU.

The fiber-optic interface can either be a single fiber interface (with WDM) or a dual head with separate Rx and Tx connectors. This is ordered as needed when the Master Unit is specified.

Each FOI can serve up to 4 Remote Units on a single fiber. The drawback is that the Remote Units must have different optical wavelengths in the uplinks to avoid interference. They can however share the same optical wavelength in the downlink.



Figure 3: Fiber optic interface

Safety and Care for fibers



The laser is a Class 3b laser that produces invisible infra-red coherent light. Avoid looking into connected fibers and receptacles. Not safe to view with optical instruments. Always put the protection caps on not used fibers and receptacles.

Every time a fiber is disconnected and re-connected care should be taken to avoid dust to settle on the connector or in the receptacle. Clean with a dry fiber cleaning tool before reconnecting the fiber at all times. A single speck of dust can impact the transmission severely. Do not touch the fiber ends with your fingers. That will leave grease on the connectors and may cause severe problems.

Functional description

The FOI has a nominal gain of 35 dB and the laser transmitter should see a maximum composite power in of ca 0 dBm. This means that for 0 dB attenuation in the DL a maximum input of -35 dBm composite power is recommended (when attenuators are set to 0 dBm). If the DL attenuator is set to a higher value the maximum recommended input is adjusted accordingly.

The output power of the laser is calibrated to 3 000 μ W. This can be used to check the loss over fiber in the remote because the remote reports the received optical levels. The loss may be different in the UL compared to the DL because of different wavelengths on the laser.

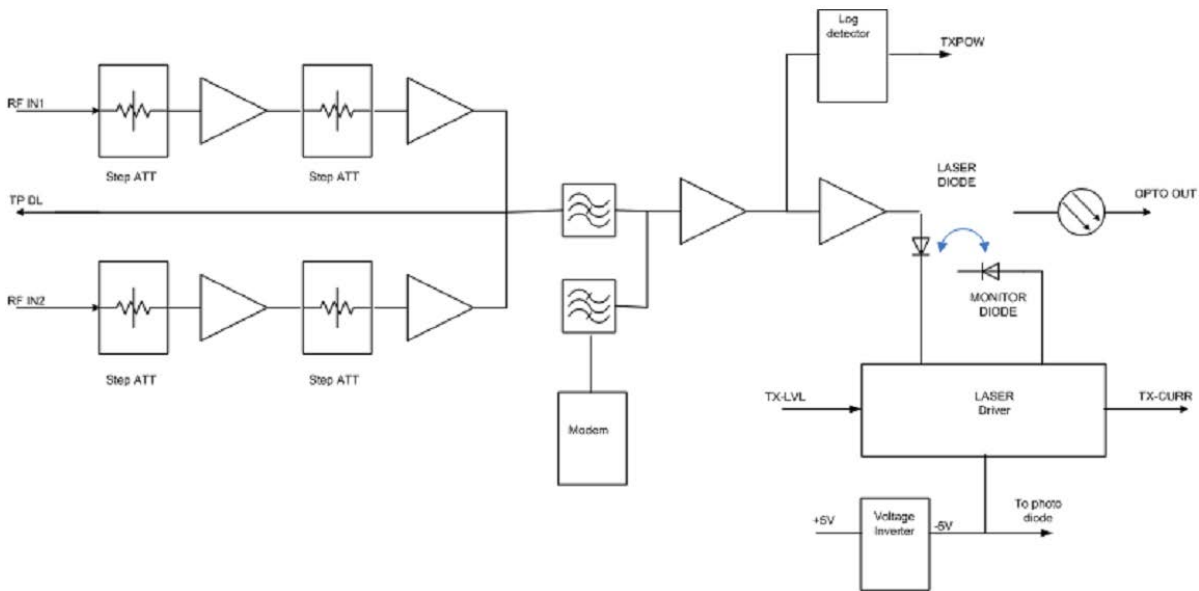
The FOI is powered from the rack backplane and communicates with Ethernet with the other modules in the Master Unit.

The unit contains several adjustable attenuators which means that it can compensate for loss before the FOI (e.g. in the POI) and for loss on the fiber in the uplink. There are two sets of RF ports on the FOI that can be used to connect signals from two different strips in the POI.

The Ethernet communication between the Master Unit and the Remote Unit takes place on two subcarriers in the FOI where the Ethernet signals are superimposed on the RF signals.

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Below is a block schematic that shows the downlink path in the FOI and how the test port is connected. As you can see there are two attenuators that can be set in the DL path, this allows for balancing the input signals from two different signal sources so that they can share the dynamics of the laser properly.

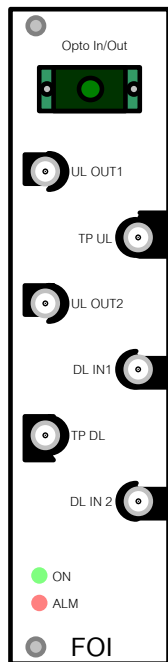


The RF drive levels are measured and accessible in the web interface so that they can be checked. In the future alarm levels may be added to these test points.

This interface is designed to work with SC-APC connectors (7° angled physical connector) and single mode fibers only. All connectors between the master unit and the remote unit should be of angled type, otherwise problems with reflections will arise which may cause severe problems in the system.

- ✓ Single mode fiber
- ✓ Angled connectors
- ✓ Optical loss < 15 dB

Interfaces of the FOI



OPTO IN/OUT

This is the receptacle for the optical fiber. The illustration shows the module with built in WDM (combined Rx/Tx). The version without WDM has a second connector where one is the Tx and the other is the Rx.

UL OUT 1/2

These are the RF ports that normally are patched to the POI for interconnecting and then on to the BIU.

DL IN 1/2

These are the RF connectors where the signal in the DL from the POI is patched into the FOI for conversion to laser light.

TP UL/DL

These are test ports that can be used to check the signal levels or noise in the system.

There are also two LEDs on the unit which can be used to check the status according to the following table:

State	ON LED	ALARM LED	Note
Booting	2 Hz	Off	Normal boot
Booting standalone mode	2 Hz	2 Hz	Not attached to rack
Booting read of MAC address failed	2 Hz	On	Error
Starting	0,1 Hz 90%	0,1 Hz 90%	Kernel startup
Operation	0,5 Hz 10%	Off	Normal operation
Operation	0,5 Hz 10%	1 Hz 10%	Minor alarm state
Operation	0,5 Hz 10%	2 Hz 25%	Major alarm state
Operation	0,5 Hz 10%	On	Critical alarm state

Table 6: LED indicators on FOI

FOI Specifications

Parameter		Value	Unit
Maximum fiber loss from MU to RU	Optical	15	dBo
Optical output power	Calibrated	3 000	μW
Maximum number of RU supported on single fiber		4	Pcs
Input RF power recommended	Composite	-50 to -35*	dBm
Power consumption		< 15	W
Temperature range	Operational	0 to 45	°C
Width		1	U
Height		3	U
Optical connector type		SC-APC	
RF connector type		QMA	Female

Table 7: FOI general specifications

*) Depends on attenuator settings. For 0 dB attenuation composite level should be < -35 dBm.

Parameter	Wavelength	
DOI 301	1310 nm	Rx and Tx separate
DOI 302 (WDM)	1310 nm	Rx and Tx on sam fiber
DOI 308x	Separate Rx and Tx various wavelengths available	

Table 8: FOI variants

The DOI 308 version can be ordered with various wavelengths. The actual wavelengths that are possible to are available upon request to info@deltanode.com.

2.1.5 PSU – the rack power supply

The power supply unit can handle up to one full shelf of other active units, such as BIU or FOI. If your system consists of more than one shelf, then another PSU is added to serve the second shelf and so on.

Functional description

The Power Supply Unit is normally delivered as a 240 VAC version for Europe and 115 VAC version for US or other countries using this voltage. If a -48 VDC telecom version is desired, contact DeltaNode.

All connectors necessary are on the front side of the power supply. The picture shows the PSU equipped with European power inlet. Output are two 10 pin Molex connectors that will be connected to the shelf the PSU is

supplying power to. One connector should always be connected to the shelf that the PSU is located in (for driving the fans).



Figure 4: MU power supply unit

One shelf can handle up to 4 power supplies. Each shelf can have two PSU:s connected to it for reduncancy.

Parameter		Value	Unit
Input power voltage	Mains	86-264	VAC
Input power frequency	Mains	50 / 60	Hz
Operating temperature		0-45	°C
Power rating		240	W

2.1.6 BGW – the management gateway

Base Station Master unit Gateway – this unit is a self-powered Linux based server. It is responsible for assigning addresses to all the modules in the system, including the Remote Units as well as their components. Modules in a Master Unit will inherit their IP addresses via DHCP leases and by way of inhering the MAC addresses from the backplane we can ensure that a new module inserted in the rack receives the same address as the one it is replacing, without any need of manual configuration.



Figure 5: BGW Base station master unit gateway

If the BGW is replaced the Remote Units may not show up immediately. This is due to the lease time on the address they have. Eventually they will request a new address and when this is done they will show up.

The BGW is the unit responsible for alarm handling and remote forward of alarms either by SMTP mail forwarding or by SNMP traps. A MIB file for your SNMP system is available from DeltaNode upon request as well as documentation regarding SNMP.

Features of the BGW

- ✓ *Web interface configuration*
- ✓ *Automatic detection of modules*
- ✓ *Automatic detection of Remote Units*
- ✓ *Can handle large systems*
- ✓ *Functions for statistics*
- ✓ *Northbound communication to CGW*
- ✓ *Includes firewall to protect local net*
- ✓ *Is the portal to your Master Unit*
- ✓ *User-provided certificate based security via HTTPS*

The BGW can also launch VPN tunnels to a remote supervision center called the Central Gateway (CGW). This way it is possible to manage multiple systems from a single place. The CGW will be described later in this manual.

The BGW has two Ethernet ports. One is connected to the internal network in the Master Unit to provide the local network for all the modules, the Remote Units and everything else. It also provides, via the built-in switch in the Master Unit, a way of locally configuring the network. It provides the web interface for all the settings of the system as well as many other functions. Secondly there is a “northbound” Ethernet port that allows the BGW to connect to the Internet, or a WAN/MAN type of larger network. This means that the system can be monitored and managed remotely.

A Virtual Private Network (VPN) tunnel can be set up from the BGW to a central location using a CGW. The CGW can handle a large number of such tunnels, providing a central point for supervising all the installations and collecting alarms and statistics from all the systems as well as centralized alarm management. The BGW can actually set up a second tunnel, which is sometimes done to DeltaNode management center where we can help with management and supervision. This is a service that we provide if needed.

The actual use and how to set up the BGW will be described in the commissioning and supervision and maintenance chapters of this manual.

Parameter		Value	Unit
Input power voltage	Mains	100-240	VAC
Input power frequency	Mains	50 / 60	Hz
Operating temperature		10-30	°C
Power rating	Typical	< 100	W
Height		1	U
Width		19	In.
Depth		360	Mm
Weight		< 5	kg

Table 9: BGW specifications

A BGW can also be set up in factory for a special need, it will then be delivered together with a restore image that allows the customer to restore it quickly in case of a hardware failure.

2.1.7 RGW – the compact remote gateway

The RGW is a small unit similar to the BGW but intended for small systems where there is a low number of remotes or where there is no head-end and therefore the RGW has a form factor that allows it to be mounted inside a repeater casing.

This can be used to run up to 4 Remote Units from a single Repeater on a single Fiber. The RGW has the capability to connect Northbound to a Central Gateway (CGW) just like the BGW does and it can also forward alarms through a VPN tunnel to a CGW.

The memory capacity and features are reduced compared to the BGW but for a small system with a single fiber this may be an option to use.

The RGW can be equipped with a modem to allow access to a system in a remote location where there is no Ethernet. The modem is usually a 3G modem which enables the RGW to set up a tunnel to a Central Gateway unit (CGW) enabling supervision, monitoring and control of the system

2.2 Remote Unit

There are many different kinds of remote units with a wide range of gain and output power to cater to many different needs. A low and medium power unit can house up to 4 different frequency bands in one unit, the high power versions can handle up to 2 different bands in one single unit.

Chassis types

RUs comes in mainly two different chassis, a single compact chassis for 1-2 bands and a dual chassis for up to 4 bands. This is how they can be configured:

Chassis type	Low	Medium	High
Single chassis	1-2	1-2	1
Dual chassis	3-4	3-4	2

Table 10: Chassis types



Figure 6: Single chassis remote

It is also possible to have combinations of the above. For example it is possible to build a dual chassis with 2 medium power bands and 1 high power band in the same remote. Each side of a dual chassis is virtually identical to a single chassis remote unit. This ensures unparalleled flexibility when building multiple operator / multiple band solutions.

A dual chassis may have 1-2 optical remote units (FOR). This way they can be fed from different directions for redundancy.

Because of the larger power amplifiers used for high power RU:s the need for more cooling and room allows only 2 bands in the same double chassis. Remotes can also be daisy-chained by way of RF cables, meaning up to two chassis can share the same fiber-optical interface providing up to 8 bands in a single location.



Figure 7: Dual chassis remote

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Below is a list of the most common remote units that are used with the DeltaNode Fiber-DAS system. Variants are available upon request.

Commonly for all Remote Units is their excellent noise figure, contributing to an overall noise figure for the whole system from remote to head-end into the base station of < 3 dB for the RF link.

Both chassis comply with IP65 protection for use in any environment. The coating is a durable coating which aids the convection cooling. No fans are used for the Remote Units. Both chassis are available both with wall and pole mounting kits as requested.

Comparison table for remote units

Product code	Pout (ETSI)*	Pout (FCC)	Bands
DDR medium power)	26-30	36	1-4
DDS (High power quad band)	30-41	41	1-4
DDH (high power)	32-43	43	1-2
DDH2 (Dual amplifiers)	N/A	46	1

Table 11: Remote comparison table

* Actual power determined by frequency band and spectrum demands.

2.2.1 DDR

Deltanode's Distributed Radio head is a high performing wideband radio head equipped with a linear power amplifier supporting all modulations. The light weight, convection cooled IP65 chassis secures the performance in almost any environment.

ETSI standard

GENERAL SPECIFICATIONS

Noise Figure	Typical	3	dB
Delay excluding optical fiber		< 0,5	µs
Power Supply	Mains	85 – 264	VAC or VDC
Operating Temperature		-25 - +55	
Casing		IP65	

OPTICAL SPECIFICATIONS

RF Frequency range		88 – 2200	MHz
Flatness		+ - 3	dB
Optical output power	Nominal	3	mW
DFB Laser output Wavelength		1270 - 1610	nm
Optical return loss		< -40	dB
Optical isolator	min	30	dB
Side-mode suppression ratio	min	30	dB
Maximum optical input power	non destructive	10	mW

SPECIFICATIONS DDR100 (Single Band) & DDR200 (Dual band)

Power Consumption, max	DDR 100 (200)	90 (180)	W
Dimensions	WxDxH	300 x 130 x 700	mm
Weight		< 12	Kg

DELTANODE FIBER DAS MANUAL

SPECIFICATIONS DDR300(Triple Band) & DDR400(Quad Band)

Power Consumption, max	DDR 300 (400)	270 (360)	W
Dimensions	WxDxH	300 x 220 x 700	mm
Weight		< 24	Kg

AVAILABLE PRODUCTS, EUROPEAN CELLULAR

System	UL Frequency MHz	DL Frequency MHz	Pout (DL) dBm/c, 1 Carrier	Pout (DL) dBm/c, 2 Carriers	Standard
TETRA, Public Safety	380 - 385	390 - 395	26	23	ETSI
TETRA, Commercial	410 - 415	420 - 425	26	23	ETSI
TETRA, Commercial	415 - 420	425 - 430	26	23	ETSI
CDMA450	453 - 457,5	463 - 467,5	33	28	FCC
GSM-R	876 - 880	921 - 925	26	23	ETSI
EGSM900	880 - 915	925 - 960	26	23	ETSI
GSM1800	1710 - 1785	1805 - 1880	28	25	ETSI
UMTS	1920 - 1980	2110 - 2170	30	25	3GPP

FCC standard

Deltanode's Distributed Radio head is a high performing wideband radio head equipped with a linear power amplifier supporting all modulations. The light weight, convection cooled IP65 chassis secures the performance in almost any environment.

GENERAL SPECIFICATIONS

Noise Figure	Typical	3	dB
Delay excluding optical fiber		< 0,5	µs
Power Supply	Mains	85 – 264	VAC or VDC
Operating Temperature		-25 - +55	
Casing		IP65	

OPTICAL SPECIFICATIONS

RF Frequency range		88 – 2200	MHz
Flatness		+ - 3	dB
Optical output power	Nominal	3	mW
DFB Laser output Wavelength		1270 - 1610	nm
Optical return loss		< -40	dB
Optical isolator	min	30	dB
Side-mode suppression ratio	min	30	dB
Maximum optical input power	non destructive	10	mW

SPECIFICATIONS DDR100 (Single Band) & DDR200 (Dual band)

Power Consumption, max	DDR 100 (200)	90 (180)	W
Dimensions	WxDxH	300 x 130 x 700	mm
Weight		< 12	Kg

DELTANODE FIBER DAS MANUAL

SPECIFICATIONS DDR300 (Triple Band) & DDR400 (Quad Band)

Power Consumption, max	DDR 300 (400)	270 (360)	W
Dimensions	WxDxH	300 x 220 x 700	mm
Weight		< 24	Kg

AVAILABLE PRODUCTS, AMERICAN CELLULAR

System	UL Frequency MHz	DL Frequency MHz	Pout, DL, dBm (Composite)	Standard
LTE LB	698 - 716	728 - 746	33	FCC
LTE UB	746 - 776*	776 – 806*	33	FCC
iDEN	806 - 824	851 - 869	33	FCC
Cellular	824 - 849	869 - 894	33	FCC
PCS1900	1850 - 1915	1930 - 1995	33	FCC
AWS	1710 - 1755	2110 - 2155	33	FCC

*Sub-bands available

AVAILABLE PRODUCTS, AMERICAN PUBLIC SAFETY

System	UL Frequency MHz	DL Frequency MHz	Pout, DL, dBm (Composite)	Nominal Bandwidth MHz	Nominal Passband Gain dB	Input/ Output Impedance Ohms	Standard
VHF	150-174	150-174	33	24(FCC); 36 (IC)*	70	50	FCC
UHF	450-512	450-512	33	62**	70	50	FCC
700	793-805	763-775	33	12	70	50	FCC
800	806-824	851-869	33	18	70	50	FCC

* 2MHz with required external duplexers

** 3MHz tor 1.5 MHz with required external duplexers

RF Exposure

The equipment operating in the 800MHz public safety band and the UHF public safety band complies with the FCC RF radiation exposure limits set forth for an uncontrolled environment. This equipment should be installed and operated with a minimum distance of **20 centimeters** between the radiator and your body.

The equipment operating in the 700MHz public safety band require a separation distance of at least **36.2cm**. This distance must be maintained between the user and antenna when the product is used with a 5.5dBi antenna.

The equipment operating in the VHF public safety band require a separation distance of at least **69.1cm**. This distance must be maintained between the user and antenna when the product is used with a 10.5dBi antenna.

If system will operate on multiple bands, the separation distance required shall be equal to, or greater than, the band with the largest separation distance.

2.2.2 DDS

Deltanode's DDS series distributed high power radio head is a high performing wideband radio head equipped with a Pre Distortion power amplifier that supports all modulations. The light weight, convection cooled IP65 chassis secures the performance in almost any environment.

FCC Standard

GENERAL SPECIFICATIONS

Noise Figure	Typical	3	dB
Delay excluding optical fiber		< 0,5	µs
Instantaneous Band Width	Max	15	MHz
Power Supply	Mains	85 – 264	VAC or VDC
Operating Temperature		-25 - +55	
Casing		IP65	

OPTICAL SPECIFICATIONS

RF Frequency range		88 – 2200	MHz
Flatness		+/- 3	dB
Optical output power	Nominal	3	mW
DFB Laser output Wavelength		1270 - 1610	nm
Optical return loss		< -40	dB
Optical isolator	min	30	dB
Side-mode suppression ratio	min	30	dB
Maximum optical input power	non destructive	10	mW

SPECIFICATIONS DDS100 (Single Band) & DDS200 (Dual band)

Power Consumption, max	DDS100/200	90 (180)	W
Dimensions	WxDxH	300 x 130 x 700	mm
Weight		< 12	Kg

SPECIFICATIONS DDS300 (Triple Band) & DDS400(Quad Band)

Power Consumption, max	DDS300/400	270 (360)	W
Dimensions	WxDxH	300 x 220 x 700	mm
Weight		< 24	Kg

AVAILABLE PRODUCTS, AMERICAN CELLULAR

System	UL Frequency MHz	DL Frequency MHz	Downlink Power RMS	Standard
LTE LB	698 - 716	728 - 746	41	FCC
LTE UB	746 - 776*	776 – 806*	41	FCC
iDEN	806 - 824	851 - 869	41	FCC
Cellular	824 - 849	869 - 894	41	FCC
PCS1900	1850 - 1915	1930 - 1995	41	FCC
AWS	1710 - 1755	2110 - 2155	41	FCC

*Sub-bands available

2.2.3 DDH

Deltanode's Distributed High power radio head is a high performing wideband radio head equipped with a feed forward multi carrier power amplifier that supports all modulations. The light weight, convection cooled IP65 chassis secures the performance in almost any environment.

ETSI standard

GENERAL SPECIFICATIONS

Noise Figure	Typical	3	dB
Delay excluding optical fiber		< 0,5	µs
Power Supply	Mains	85 – 264	VAC or VDC
Operating Temperature		-25 - +55	
Casing		IP65	

OPTICAL SPECIFICATIONS

RF Frequency range		88 – 2700	MHz
Flatness		+ - 3	dB
Optical output power	Nominal	3	mW
DFB Laser output Wavelength		1270 - 1610	nm
Optical return loss		< -40	dB
Optical isolator	min	30	dB
Side-mode suppression ratio	min	30	dB
Maximum optical input power	non destructive	10	mW

SPECIFICATIONS DDH100(Single Band)

Power Consumption	Typical	210	W
Dimensions	WxDxH	300 x 130 x 700	mm
Weight		< 14	Kg

SPECIFICATIONS DDH200(Dual Band)

Power Consumption	Typical	420	W
Dimensions	WxDxH	300 x 220 x 700	mm
Weight		< 28	Kg

AVAILABLE PRODUCTS, EUROPEAN CELLULAR

System	Number of carriers							
	2		4		8		16	
	Composite Power	Power per carrier	Composite Power	Power per carrier	Composite Power	Power per carrier	Composite Power	Power per carrier
TETRA	32	29	33	27	33	24		
EGSM900	40	34	40	34	40	31	40	28
GSM1800	40	37	40	34	40	31	40	28
UMTS	43	40	43	37	43	34	43	31
2600	43	40	43	37				

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FCC standards

GENERAL SPECIFICATIONS

Noise Figure	Typical	3	dB
Delay excluding optical fiber		< 0,5	µs
Power Supply	Mains	85 – 264	VAC or VDC
Operating Temperature		-25 - +55	
Casing		IP65	

OPTICAL SPECIFICATIONS

RF Frequency range		88 – 2200	MHz
Flatness		+– 3	dB
Optical output power	Nominal	3	mW
DFB Laser output Wavelength		1270 - 1610	nm
Optical return loss		< -40	dB
Optical isolator	Min	30	dB
Side-mode suppression ratio	Min	30	dB
Maximum optical input power	non destructive	10	mW

SPECIFICATIONS DDH100(Single Band)

Power Consumption	Typical	210	W
Dimensions	WxDxH	300 x 130 x 700	mm
Weight		< 14	Kg

SPECIFICATIONS DDH200(Dual Band)

Power Consumption	Typical	420	W
Dimensions	WxDxH	300 x 220 x 700	mm
Weight		< 28	Kg

AVAILABLE PRODUCTS, AMERICAN CELLULAR

System	UL Frequency MHz	DL Frequency MHz	Pout, DL, dBm (RMS)	Standard
LTE LB	698 - 716	728 - 746	43	FCC
LTE UB	746 -776*	776 – 806*	43	FCC
iDEN	806 - 824	851 - 869	40	FCC
Cellular	824 - 849	869 - 894	43	FCC
PCS1900	1850 - 1915	1930 - 1995	43	FCC
AWS	1710 - 1755	2110 - 2155	43	FCC

*Sub-bands available

All specifications subject to change without notice.

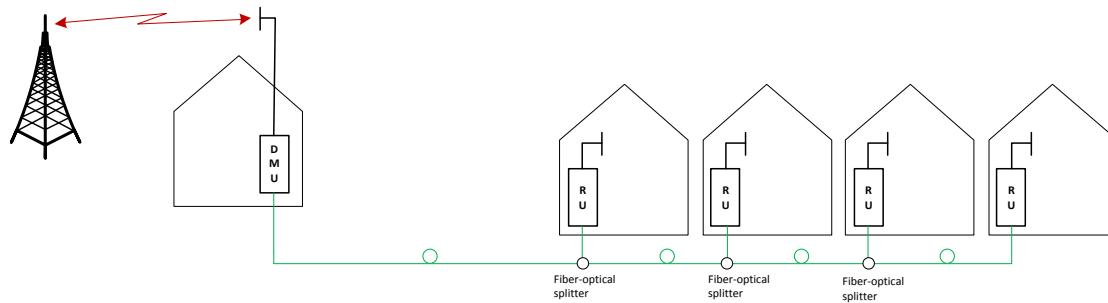
2.2.4 DMU – Remote head end

Deltanode's DMU100 series is pickup repeater that can provide the signals over fiber to a Master Unit or directly to up to 4 Remote Units. When the DMU is used to transmit the signals to a Master Unit, the ordinary BGW is used to control the system, but in case the Master Unit is not needed and it connects directly to up to 4 Remote Units the DMU can be equipped with the compact gateway, RGW, to provide for the settings and alarm handling for the entire system.

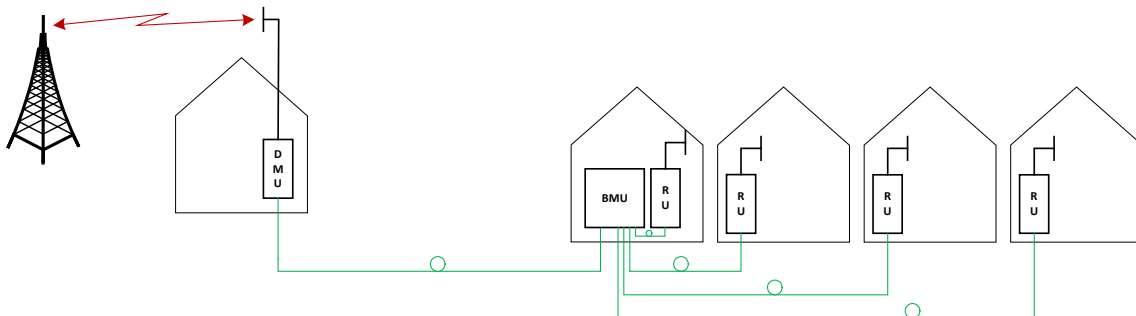
Remote communication can be done either over Ethernet if that exists in the location, or the unit can be equipped with a modem that allows it to set up a tunnel to a Central Gateway CGW where it can be controlled properly. The modem is normally a standard 3G modem but options may be possible if needed.

It is possible to build the DMU with more than one band. However, depending on the types of bands and the necessary duplexers it may need to be verified with DeltaNode that your combination of bands are possible if the RGW is to be included.

The chassis is the same as for the DeltaNode Remote Units (single chassis) and can handle a single band.



In the above example the DMU is used to pick up the signal at a remote location and then it is transmitted on the fiber to four different locations that need coverage. The RU can be connected to coaxial spreading networks if needed.



In the above figure the DMU is feeding a Master Unit (BMU) which in its turn feeds the Remote Units (RU). This is a far more flexible solution and should be preferred when it is possible.

The DMU is usually not equipped with a powerful Power Amplifier (PA) in the uplink because the idea of using it is to place the repeater where there is a good signal. The power level matches that of a mobile phone.

3 System design

Fiber-DAS is a way of distributing radio signals from a base station to a remotely located antenna where the coaxial cable losses would be too high or there is impractical to install coaxial cables. Fiber-DAS can be used indoor to cover large building where outside penetration of radio signals is not enough, it can be used to cover structures such as tunnels for rail and road, airports, metro lines and many other places.

This part of the manual aims at giving you some idea on how to do your systems design and avoid common pitfalls. All fiber-DAS share some common properties as they are an extension of an existing signal into an area where there is little or no coverage.

3.1 The basics

There are some basic knowledge you should be familiar with when you design your system. In this part we will go through the most important ones and help you get through the design of your system.

A link budget is a way of calculating the required signal levels for the base station and the mobile station and matching this against your system design, the losses in the cables, the antenna factors and other such parameters goes into a link budget.

When you have done a rough link budget you should use the DAS calculator and calculate the settings of each uplink and downlink in the system.

Example: You have a system with 3 remote units and they are all dual band 850/1900 for CDMA and GSM. Your system has 6 uplinks and 6 downlinks where the signal may proceed from antenna to base station or vice versa, in unit one there is one 850 RF strip and one 1900 RF strip forming two RF chains with uplinks and downlinks.

The DAS calculator may yield a different noise figure from the one you initially assumed when you did your link budget. This is fine, you may insert the new noise figure in your link budget and observe the result.

When you have done your calculations you already know the settings of the system in principle and you can now commission it. Using the settings from the DAS calculator as a basis you can connect to the system and set it up one unit at a time, more about that in chapter 5 *Commissioning* of the system.

3.2 Link budgets

The starting point is to create a viable link budget for your system. As link budgets are calculated different for different systems you may want to take some time and study typical link budget calculations for the type of services you are using.

You do not need to create link budgets for all of your remotes and all frequency bands. Do it for the worst case only for each service, that should be enough. This is the normal procedure and it is usually not difficult to find the worst case scenario. Look for the highest loss between the base station and the antenna, including the fiber loss between Master Unit and Remote Unit and any split loss after the Remote Unit until you get to the last antenna.

If you are using radiating cables, then calculate with the loss over the maximum length of radiating cable you need to support and find the Remote Unit that has the highest total loss from the User Equipment (mobile station) to the Base Station end.

3.2.1 Downlink

For the downlink you can usually just use the output power of the remote unit and then calculate your link budget. Remember that if you have several carriers, you need to calculate your link budget with this in account. For each new carrier you add, the power per carrier goes down as the power on the Remote Unit is divided onto all the (active) downlink carriers.

To calculate the “per carrier” output power here is a general table of modifiers that are applied to the output power of the remote unit:

1	2	3	4	5	6	7	8	9	10
0	-3,0	-4,8	-6,0	-7,0	-7,8	-8,5	-9,0	-9,5	-10,0

Table 12: Per carrier loss

As you can see there is a correlation that whenever the number of carriers double the per carrier power is lowered with another 3 dB. Thus the formula for any number of carriers will be:

$$P_{carrier} = P_{composite} - 10 \cdot \log_{10}(N_{carriers})$$

The output power for each type of remote unit and frequency band can be found in the data sheets in chapter 2.2 *Remote Unit* where the relevant parameters for each remote system are discussed.

Remember to use the per carrier power in your link budget and not the composite because if as you keep adding carriers to the system the power per carrier will be lower. If you are planning on adding additional carriers in the future you should plan your system for the maximum foreseeable number of carriers.

Following is an example of a link budget. This link budget is also included in the DAS Calculator package. If you do not have this package contact DeltaNode Solutions to receive a copy.

3.2.2 Uplink

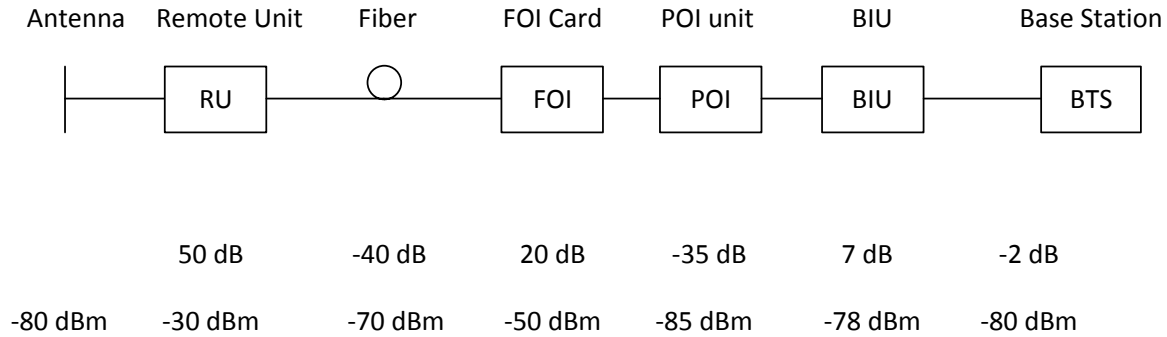
Uplink calculations generally rely on having the noise figure at hand before so that the desensitization of the base station can be calculated. However since the noise figure is dependent on the link budget, we should be able to calculate a crude link budget at first, get our gain straight and then when we are done we should be able to calculate the proper noise load using the DAS Calculator Tool (will be handled in chapter 6). Therefore we will assume a standard noise figure for now, properly adjusted the DeltaNode Fiber-DAS solution has a NF of less than 3 dB per uplink.

A reasonable assumption for the NF is around 3 dB, if we should get a better or worse NF later when the DAS Calculator is employed we will just go back and correct the link budgets for this.

System Uplink Net Gain

The net gain is the total gain in the uplink from the Remote Unit port to the input port on the base station. This chain looks something like this:

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In the illustration above there is an input signal to the remote of -80 dBm. Then each step of the chain has gain or attenuation as shown, the fiber loss is in total 40 dB, the FOI is set to 20 dB gain, the loss through the POI is 35 dB, the BIU is set to 7 dB gain and the loss on the jumper between the Master Unit and the Radio Base Station is 2 dB.

This means that the signal level entered into the Remote Unit is seen by the base station. This is considered an optimal point setting for the uplink when it comes to signal level. If the net gain in the uplink is positive, we also put noise on to the base station and will desensitize its receiver. This may not be a problem, if the Base Station is dedicated to only the Fiber-DAS system then a positive net gain is not a problem because any desensitization caused by increased gain is compensated by an equal increase in the useful signals level. Thus maintaining the same C/I.

However if the Base Station is also covering an outdoor area or has other antennas connected to the same sector then a positive net gain will cause a desensitization of the receiver for the *other antenna* and this is generally speaking a bad thing.

The system also has a thermal noise load that it will put on the base station, just like an antenna. The noise figure of the system can be determined by using the Fiber-DAS calculator excel sheet detailed in chapter using the Fiber-DAS calculator detailed later in this manual. The total noise is also an accumulation of the noise posed by each chain and the net gain of the system.

If we have a system with 4 equally set up chains, and each chain has a noise load of 3 dB and the net gain is 0 dB then the noise load on the system will be around 9 dB.

If we decrease the net gain in the uplink we can lower this noise as the system NF can be construed as the NF + Net gain uplink times the number of equal chains. Since the chains are not in fact equal, they will have different NF and different gain slightly it may be a good idea to calculate the total noise load:

Chain	NF	Gain	N. Load	Comment
1	3,2	-1,2	2,0	
1	2,3	+2,3	4,6	
2	2,8	+4,0	6,8	This is very high
3	4,0	-2,8	1,2	
Total			10,2	

By lowering the net gain to -5 dB on all chains we get the following:

Chain	NF	Gain	N. Load	Comment
1	3,2	-5	-1,8	
1	2,3	-5	-2,7	
2	2,8	-5	-2,2	

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3	4,0	-5	-1	
Total			4,1	Similar to a BTS own NF

This is similar to the BTS own noise figure which generally is 2-4 dB depending on the system. This kind of desensitization then becomes a tradeoff between coverage area in the uplink and the noise load on the base station.

Adding noise from each parallel chain is then done through the formula:

$$NL_{Total} = 10 \cdot \log_{10} \left(10^{\frac{NF1+G1}{10}} + 10^{\frac{NF2+G2}{10}} + \dots + 10^{\frac{NF_n+G_n}{10}} \right)$$

NF is the noise figure for each chain

NL is the total noise load

G is the gain of the chain in total

Note: This is different from Friis formula where the noise sources are cascaded, here each noise contribution are just added in linear and then converted back to decibels.

When the sensitivity has been calculated it is time to make a proper link budget and find out if the system will cover the expected areas.

Here are some examples on link budget calculations where you can insert the noise figure of the system. These calculations are also included on the DAS calculator tool and link budgets for other systems should also be included. CDMA can be calculated similarly to WCDMA if the gross data rates etc are corrected.

Example of GSM link budget

Linkbudget GSM with Fiber DAS			
DOWNLINK			
Output power DAS remote unit	30,0	dBm	
Number of carriers	2,0	pcs	This gives the per carrier power
Power per carrier	27,0	dBm	
Splitloss from RU port to last antenna	6,0	dB	
Cable losses	4,0	dB	
DAS antenna gain	3,0	dB	
EIRP	20,0	dBm	
MS Noise floor	-121,0	dB	
MS NF	3,0	dB	
MS C/I	12,0	dB	
MS Fading margin	6,0	dB	10 dB for vehicle movements
Penetration loss	0,0	dB	Used for in vehicle (10 dB for car)
Antenna gain MS	1,0	dB	
Body loss MS	5,0	dB	
Required signal level	-96,0	dBm	Design target
Allowed path loss from antenna to MS	116,0	dB	
Radiating cable coupling loss C95	70,0	dB	Only when using radiating cable
Loss per 100 m	4,0	dB	Only when using radiating cable
Maximum length of radiating cable	1149,5	m	

UPLINK			
Spectral noise floor of BTS	-121,0	dBm	
Noise figure BTS	3,0	dB	
C/I for BTS	9,0	dB	
BTS original noise floor	-118,0	dBm	
BTS original sensitivity	-109,0	dBm	
Fading margin	6,0	dB	

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Fiber DAS thermal noise floor	-121,0	dBm	
Noise figure DAS link	3,0	dB	
Number of equal links	3,0	pcs	
System net gain	0,0	dB	If your noise load is high you should lower this
DAS Noise result	-118,0	dBm	
Noise load on BTS with DAS	-115,0	dBm	
Desensitization on BTS	3,0	dB	
New BTS Sensitivity	-106,0	dBm	
Loss from BTS to remote antenna	7,0	dB	
Sensitivity at remote antenna	-99,0	dB	
Fading margin	6,0	db	
Penetration loss	0,0	dB	
Antenna gain MS	1,0		
Body loss MS	5,0		
Required signal level	-89,0		
MS Output power	30,0	dBm	For 900 use 33 dBm for 18/1900 bands use 30
Allowed path loss from MS to antenna	119,0	dB	
Balance downlink-uplink	-3,0	dB	This should preferably be +/- 5 dB
Radiating cable coupling loss C95	70,0	dB	Only when using radiating cable
Loss per 100 m	4,0	dB	Only when using radiating cable
Maximum length of radiating cable	1224,5	m	

Table 13: Link budget downlink

Example WCDMA link budget

WCDMA LINK BUDGET			
RECEIVER SENSITIVITY AND NOISE			
Noise floor	-108,2	dBm	
Receiver NF	6,0	dB	
RX noise power	-102,2	dBm	
Interference margin	3,0	dB	
RX interference power	-102,2	dBm	
Noise plus interference power	-99,2	dBm	
Requested bit rate	64,0	kbit	Video call = 64, voice = 12,2
Gross bit rate	3840,0	kbit	
Process gain	17,8	dB	
Required Eb/No	5,0	dB	
Fast fading margin	4,0	dB	
Receiver sensitivity	-107,9	dBm	
DOWNLINK CALCULATION			
Output power DAS remote unit	30,0	dBm	
Number of carriers	1,0	pcs	This gives the per carrier power
Power per carrier	30,0	dBm	
Splitloss from RU port to last antenna	6,0	dB	
Cable losses	4,0	dB	
DAS antenna gain	3,0	dB	
EIRP	23,0	dBm	
MS Antenna gain	5,0		
MS Body loss	3,0		
MS Minumum level	-109,9	dBm	
Allowed pathloss	137,9	dB	
UPLINK CALCULATION			
Output power of MS	21	dBm	Maximum power
Antenna gain MS	5,0	dB	
Body loss MS	3,0	dB	

EIRP MS	23,0	dBm	
Uplink net gain	-10	dB	
Sensitivity at RU port	-117,9	dBm	
Splitloss from antenna to RU	6,0	dB	
Cable losses from antenna to RU	4,0	dB	
DAS antenna gain	3,0	dB	
Antenna sensitivity	-110,9	dBm	
Allowed pathloss uplink	133,9	dB	
Balance downlink-uplink	4,0		

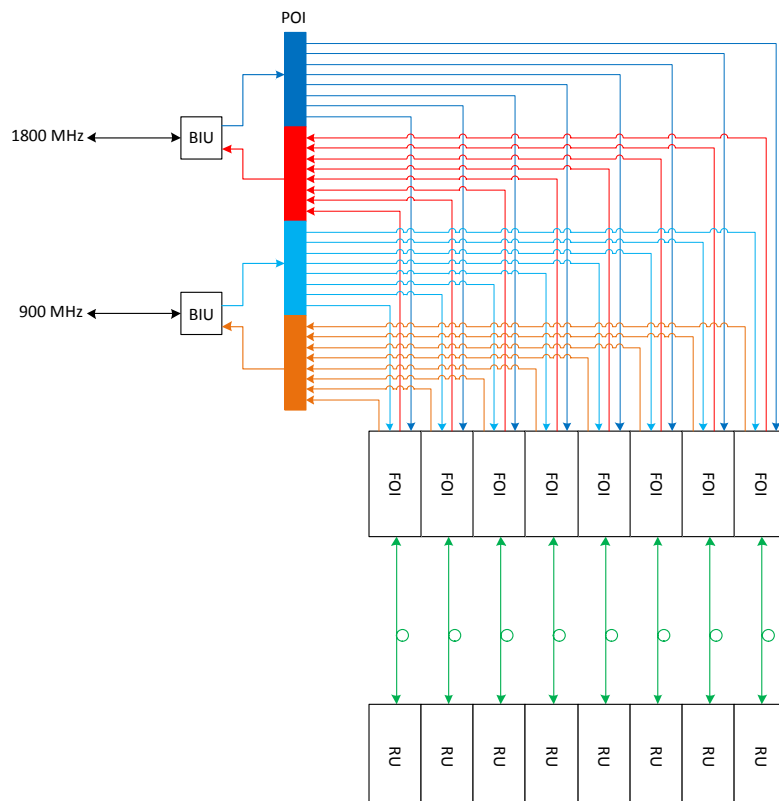
3.3 Multiple bands

The flexibility of the system allows for up to 4 bands in one remote for the low and medium power remote units. The high-power version allows 2 bands in the same chassis, mainly because the power amplifiers are more bulky.

This means that it is very easy to deploy a system for different bands. The fiber link is ultra wide band and can be used between 88 MHz up to 2 700 MHz thus covering from the VHF end of the spectrum up to the latest LTE bands.

Each band needs to have their separate BIU in the Master Unit. The uplink and downlink signals can then be combined in the POI or may be separate all the way into the FOI. The FOI has two inputs and outputs and can thus be connected to two bands directly.

Here is a block schematic on how to connect a dual band system.



The above illustration shows two BIU cards interfacing with two Radio Base Stations. In this case they could be a 900 GSM station and one 1800 GSM station as an example. It could in fact be any combination of service and frequency band such as LTE-900 or WCDMA 850.

Each BIU has a combined UL/DL port towards the base station and on the other side there are separate UL/DL ports. The BIU has an uplink amplifier and a downlink attenuator that can be set. The signals are then connected to the POI's 4 coupling fields to it's common ports. The signal is then split onto 8 ports in the downlink and combined from 8 ports in the uplink. From the POI there are then patches to each FOI card in the frame (8 in this illustration per uplink and downlink) and the 900 and 1800 signal are kept separate until the FOI.

It is not necessary to keep them separated; they could be combined for a common uplink and downlink. However, doing so means that you have fewer options in adjusting the signal levels with the gain block and attenuators, in each RF chain.

3.4 Multiple operators

The same way as multiple bands and services can be connected to the Master Unit it is also possible to connect several operators. In fact this is one of the key strengths of a Fiber-DAS system because it is access technology agnostic. This means that it is possible within the same band to mix different access technologies – if care is taken to avoid problems when mixing GSM and CDMA in the same system because of the very slow and unsophisticated power regulation in the GSM uplink.

When designing such a system, care should be taken to place the antennas to avoid any users getting too close and causing the Remote Unit to go into limit mode.

3.4.1 Base station interface

It is recommended that each operator operates their own BIU because otherwise the settings of the BIU may affect more than one system or service. This way depending on the settings of the individual Base Station the BIU can be adapted properly to get the most out of the system.

3.4.2 Remote Unit

Multiple operators can share one remote unit. Doing so means that consideration should be given to the number of carriers from each operator, so that they can fulfill their respective link budgets. If the operators have a large number of carriers, such as for some GSM operators who easily have 6, 8 even 12 carriers it would be better to split them up on separate amplifiers in the Remote Unit or even separate units altogether.

3.4.3 FOI

The FOI can be shared among the operators. It is recommended to see to that the downlink signal levels are similar so that they share the available bandwidth of the laser properly. Similarly in the uplink

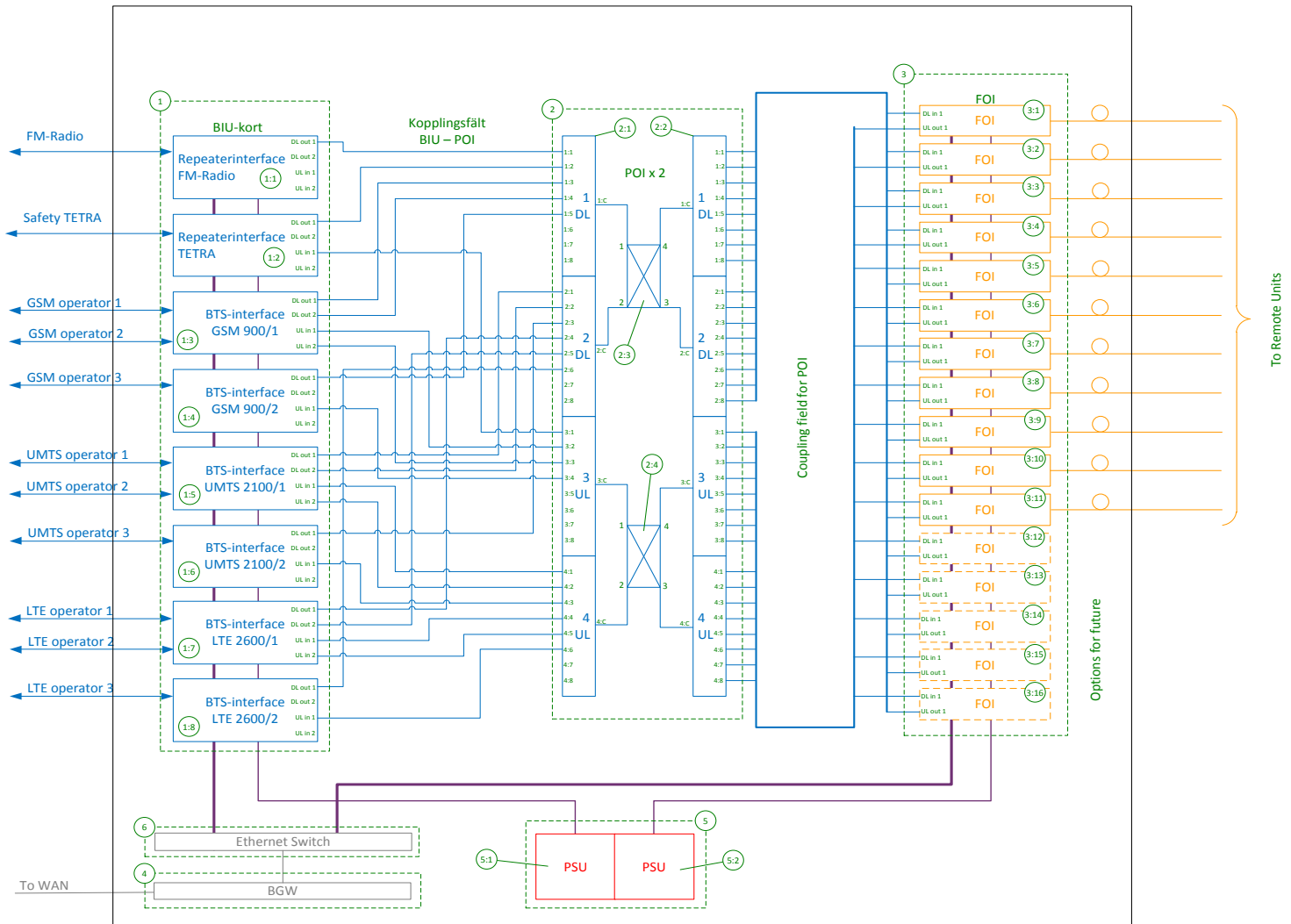
3.4.4 POI

When combining multiple operators it is often useful to combine all the operators' uplinks and split all the downlinks on a per-band basis. This means that if you have more than one FOI in the system you should likely need to use another one plus a hybrid combiner/splitter.

Here is a schematic on how this can be achieved:

3.5 Full system example

Here is an example of a full system showing the Master Unit and the fibers that goes off to the Remote Units (not shown in this example) with multiple operators and a large number of frequency bands.



Block 1: Here are all the Base Station Interface Units (BIU) cards for all the frequency bands and the operators. In this example two operators may share one BIU. The first unit 1:1 is for FM radio which is only Downlink as it is broadcast. The second unit 1:2 is for a safety blue light service using the TETRA system on 400 MHz. Then there are two BIU's 1:3 and 1:4 for GSM 900, similar for GSM 1800 and for UMTS 2100 and LTE 2600.

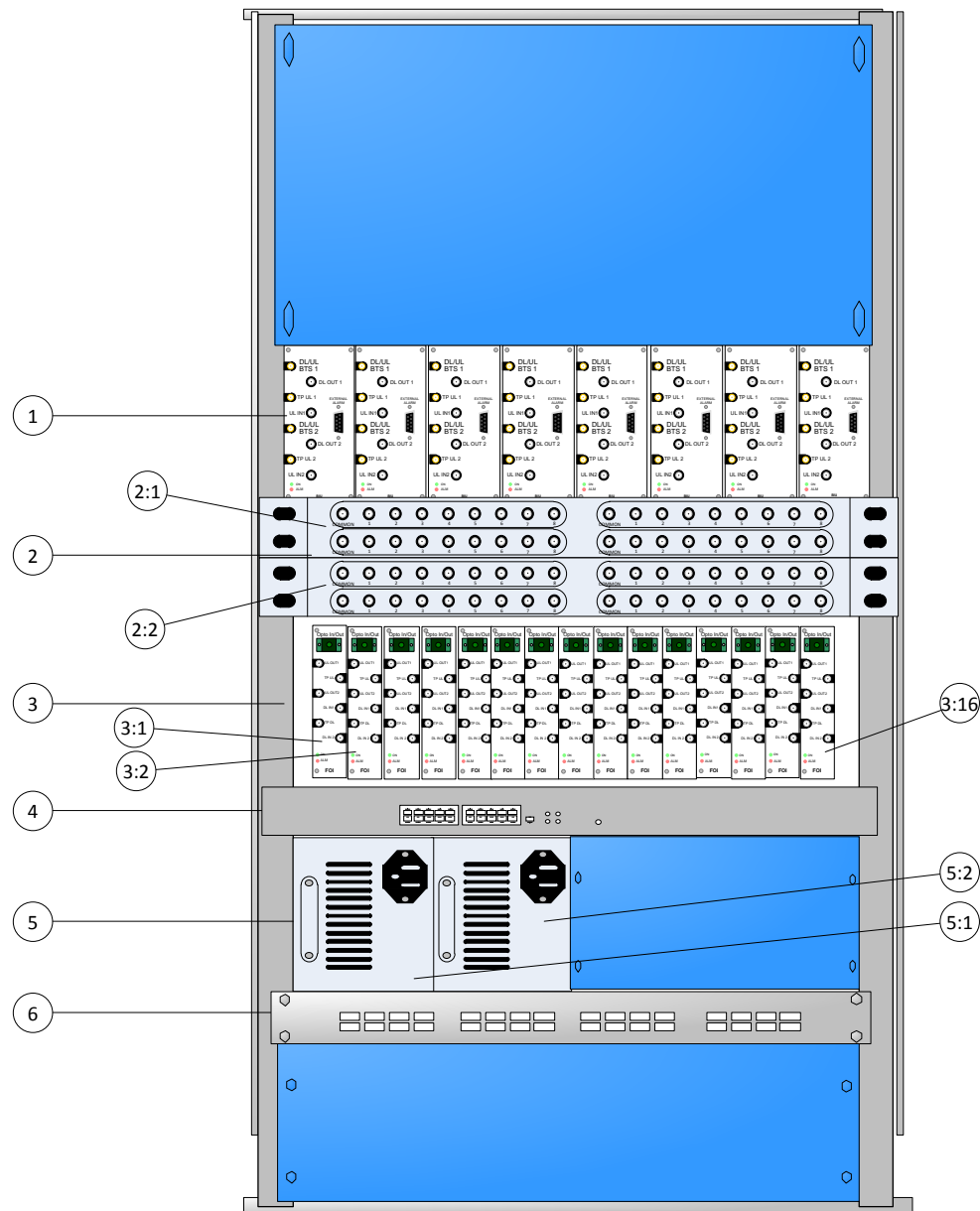
Block 2: This is the Point of Interconnect (POI) where all the signals from the operators are combined on the four coupling fields of the first POI. There are two UL fields and two DL fields. The common ports are then fed into a hybrid combiner and on to the second POI where the signals are split up to connect to all the Fiber-optic Interfaces.

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Block 3: These are the fiber-optic interfaces (FOI) and in this example up to 16 FOI cards may be connected for a total of 16 Remote Units if there are one Remote Unit per fiber. It is possible to use up to four Remote Units on a single fiber.

Block 4-6: These are supporting units such as power supplies, the BGW which is the alarm and control computer in the system and the Ethernet Switch that connects the communication between all units in the Master Unit and also handles the communications with the Remote Units.

When all this is fitted into a standard 19" rack it may look like this:



The numbers in the circles refer to the numbers on the previous connection drawing. The first frame holds all the BIU interfaces. For clarity the interconnecting cables are not shown here. The second frame is the 2 POI units and the hybrid is hidden inside the cabinet.

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The third shelf is the FOI cards, up to 16 cards can be held in one such frame. Then there is the BGW computer tying all the communication together and providing the web interface for setting up and controlling the system. The BGW also has an optional “northbound” firewalled connection that can be connected to your own network for remote supervision, alarm and control. It can even be tunneled over the Internet providing there is a CGW unit where the tunnel terminates.

Beneath the BGW are two PSU:s. They can be upgraded to four units to provide redundancy for this example, two different PSU:s can feed the same frame.

The Ethernet Switch is located at the bottom and here is where you connect a laptop to setup and commission the system.

4 Installation guidelines

WARNING

This is NOT a consumer device.

It is design for installation by **FCC LICENSEES** and **QUALIFIED INSTALLERS**. You **MUST** have an **FCC LICENSE** or express consent of an FCC licensee to operate this device. You **MUST** register Class B signal boosters (as defined in 47 CFR 90.219) online at www.fcc.gov/signal-boosters/registration. Unauthorized use may result in significant forfeiture penalties, including penalties in excess of \$100,000 for each continuing violation.

For CMRS 817-824MHz Applications:

WARNING

This is NOT a consumer device.

It is design for installation by **FCC LICENSEES** and **QUALIFIED INSTALLERS**. You **MUST** have an **FCC LICENSE** or express consent of an FCC licensee to operate this device. Unauthorized use may result in significant forfeiture penalties, including penalties in excess of \$100,000 for each continuing violation.

This device complies with part 15 of the FCC rules. Operation is subject to the following two conditions:
(1) This device may not cause harmful interference and (2) this device must accept any interference received, including interference that may cause undesired operation.

4.1 Health and Safety

Deltanode DAS system is an advanced system and should be handled by skilled staff. Deltanode are happy to offer training of installation service providers in the case this is necessary.

Read all available documentation and warnings before handling the equipment. Equipment failures due to improper handling are normally not covered by the product warranty.

Respect all warning signs on the equipment and in the documentation. Make sure to only operate the equipment on frequencies allowed to use. Do not modify the equipment. The equipment contains a Class 3B laser and the equipment is Class 1. Do not look into the Laser beam directly or indirectly, it is strong invisible light and may cause serious damage to human eyes.

Always use protective hat on fiber and connector end when fiber is removed from socket. Always clean socket and connector after a fiber has been removed before you re-attach it again.

Make sure to keep passwords and other operational information away from unauthorized personnel.

4.2 Installing the Master Unit and Remotes

All equipment must be properly grounded. This means that the ground peg in the mains connector for both head-end gear (Master Unit) and remote gear (Remote Units) must be connected to Phase, Neutral and Ground in a proper way before the plug is inserted in the unit.

The chassis of the remote and the rack of the master unit should be grounded to a potential bar or safety grounding bar when operated. All electrical installations should be done by a certified electrician only.

5 Commissioning

5.1 Preparations

The minimum of preparations necessary are to have the system documentation which should include the following items at least:

- The system layout and block schematic
- A connection diagram for the head-end Master Unit
- The type of connectors and tappers used to interface to the base station ports
- The number of carriers for each of the BIU that the base stations connects via
- Maximum output power for each service from the base stations
- Fiber losses should be documented beforehand so that you can compare what the system actually measures
- Sectorization information, which sectors should go to which remotes
- DAS calculator sheets showing the expected settings for each of the RF chains in uplink and downlink.
- Information about Ethernet connection if the system should be monitored by remote. How to connect it to the Internet for remote viewing unless you are using a modem.

5.1.1 Necessary tools

The tools necessary to commission the system includes:

- One laptop for changing the system settings, checking any alarms and status. Only software needed is a web browser. Operating system can be Windows, Linux or Mac as you prefer.
- Spectrum analyzer to measure the uplinks. The system relies on test tone measurements in the uplink and therefore it is important to have equipment to measure them
- SMA tool to be able to connect or disconnect BTS cables from the BIU.
- QMA adaptor so you can measure signals directly on the head-end units such as the FOI, BIU, POI and so on.

5.1.2 Software

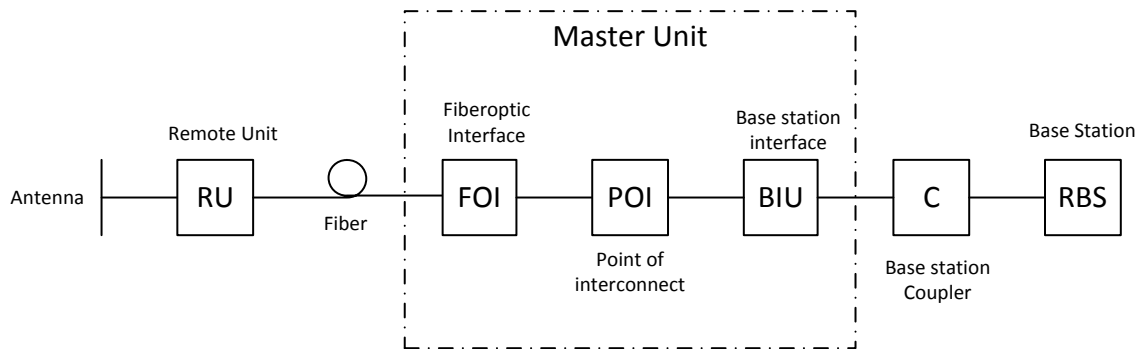
No particular software is necessary except a modern graphical based web browser.

6 RF Commissioning

In order to make the process more clear for this part of the manual we will consider setting up a fictitious system, but based on a standard approach at doing Fiber-DAS. The system that we are considering will have two frequency bands, let's assume GSM 900 MHz and UMTS 2100 MHz. The example will have 2 sectors with two remotes in each sector. Of course your system may look different, be more or less complex but in order to make it clear how the system is set up this should provide you with a starting point.

6.1 Setting up the uplink

Setting up the downlink means to adjust the system for an optimal working point from the antenna port of the Remote Unit to the actual input on the Radio Base Station. This can be done in different ways depending on how the system is designed. We will here discuss a standard set-up starting with a small block schematic showing how the system is connected.



The main parameter that we will be discussing is the "net gain" of the system. This means the total change in signal from the Remote Unit antenna port to the receiver port on the base station. There are different ways of setting this system up but we will look at a 0 dB net gain system which is a good starting point for most systems.

The system gain can be calculated as the gain in the Remote Unit – Loss on fiber + FOI gain – POI loss + BIU gain – coupler loss. Basically this takes form of a link budget and here is an example:

System part	Gain [dB]	Accumulated [dB]
Remote Unit	40	40
Fiber	-10	30
FOI Gain	20	50
POI Loss	-35	15
BIU Gain	0	15
Coupler loss	-15	0

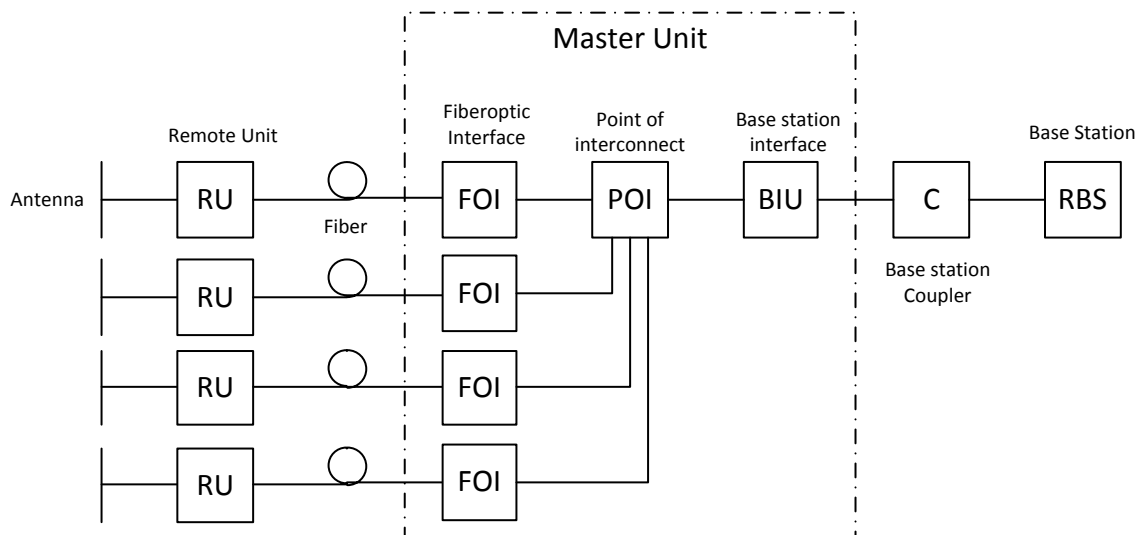
Basically this means that whatever is input at the antenna will also be seen at the same level for the Radio Base Station receiver. This is not a bad starting point but does not take into account the noise load on the base station which will increase somewhat with this setup

6.1.1 Noise load on Radio Base Station

The system will inevitably add some noise to the receiver. Properly set up the noise figure in a system like this will be better than 3 dB. However, if the gain is set up poorly (not enough gain in the remote, too much gain in the head-end) it is possible to create a very bad noise figure. In order to avoid this the Fiber-DAS Calculator should be used to calculate the noise figure of the system in the uplink.

If you have not familiarized yourself with the Fiber-DAS Calculator then I suggest you do so before moving on in this manual. The figures in the Fiber-DAS calculator relates to the settings of all steps in the chain. By using the calculator you can figure out the proper settings once you know the fiber loss between the Remote Unit and the Master Unit.

Let us assume you have arrived at a Noise Figure NF of 3 dB for this chain. However your system may contain more remotes, perhaps connected like this:



Now the noise load can be calculated by adding the noise contribution from each step of the chain. Below is an example of noise figures from each of the remotes:

Chain	NF	Gain	Noise Load
RU 1	2,8	0,0	2,8
RU 2	3,2	1,0	4,2
RU 3	3,8	-2,0	1,8
RU 4	2,6	-1,0	1,6
Sum of noise load			8,7
Base station	4,0		
Fiber-DAS noise load	8,0		
Total noise into BTS	9,5		
Desensitization	-5,5		

There is a sheet in the Fiber-DAS calculator that lets you add your figures and that will calculate it for you.

What we see here is that if we set the system up in this fashion we will desensitize the base station with about 5,5 dB. This can be okay if the base station coverage is only through the Fiber-DAS system but if the base station is also being used for outdoor coverage it is not good. We need to change the net gain

to reflect this. In general we should lower our so that we desensitize the BTS only about 3 dB. This value is a good compromise and similar to adding a second antenna to the same receiver port (which is kind of what we are doing with the Fiber-DAS).

Here are the new values:

Chain	NF	Gain	Noise Load
RU 1	2,8	-5,0	-2,2
RU 2	3,2	-5,0	-1,8
RU 3	3,8	-5,0	-1,2
RU 4	2,6	-5,0	-2,4
Sum of noise load			4,1
Base station	4,0		
Fiber-DAS noise load	4,1		
Total noise into BTS	7,1		
Desensitization	-3,1		

As you can see we should set the system up with a net gain of about -5 dB. Going back to the settings we had before which was:

System part	Gain [dB]	Accumulated [dB]
Remote Unit	40	40
Fiber	-10	30
FOI Gain	20	50
POI Loss	-35	15
BIU Gain	0	15
Coupler loss	-15	0

We only need to change the BIU setting using the attenuators in the BIU to lower the gain with 5 dB. This will accomplish what we need to do and the uplink should then be commissioned.

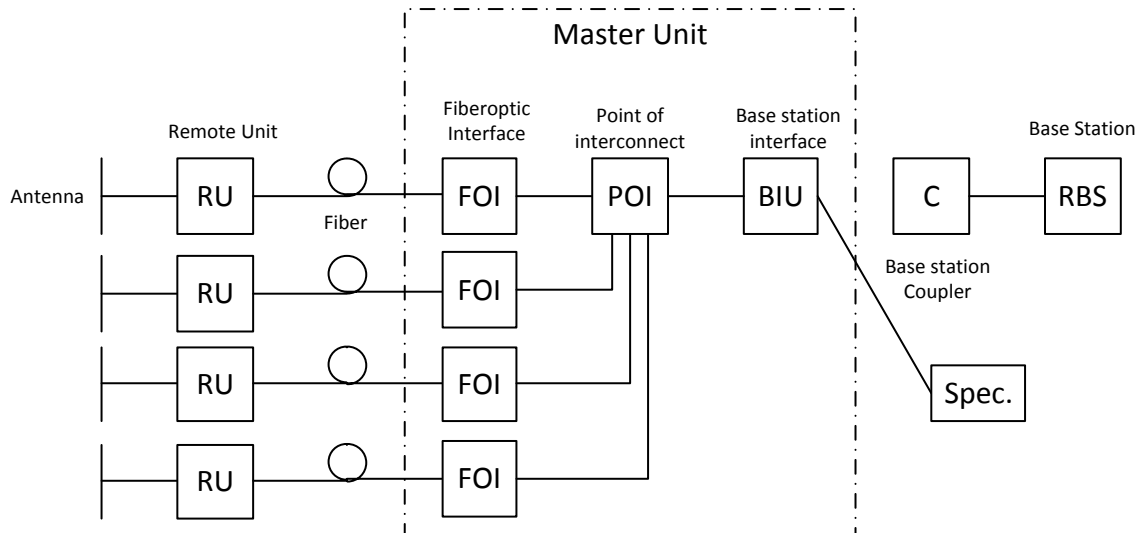
6.1.2 Practical approach

Now that we know what we should have we can easily set the system up. You need a spectrum analyzer to do this and it is easiest to connect it into the BIU port. Remember that when you measure here, the signal should also go through the BTS coupler before it reaches the base station receiver port. Therefore you should expect to read a value that is

Your expected gain + the loss in your coupler

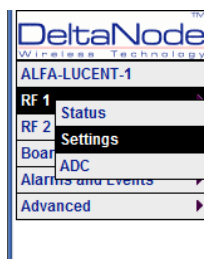
If you want a net gain of -5 dB and you have a 15 dB coupler, you should read a net gain of +10 on the BIU port. This is now what we are going to use in the following example.

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Turn on the RF

Connect to the BIU and turn on the RF. Set the attenuator in the medium range for the uplink that you are measuring. This allows you later to adjust it up and down as necessary to get the correct gain for the uplink chain.

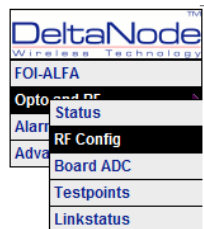


Attenuator and RF Settings, RF 1

Parameter	Value	Status
Att. Downlink	10 dB	OK
Att. Uplink	10 dB	OK
RF ON	Yes <input checked="" type="radio"/> No <input type="radio"/> ?	OK
DL Supervision ON	Yes <input checked="" type="radio"/> No <input type="radio"/> ?	OK
<input type="button" value="Submit"/>		

Setting them to 10 dB is a good idea. DL supervision can be left as is for now and also DL attenuation which we will set up later.

Connect to the FOI card and select Opto and RF – RF Config and set it up according to your Fiber-DAS calculator settings. Do not forget to turn RF on.



Opto and attenuator settings

Parameter	Value	Status
Att.1 Downlink 1	5 dB	
Att.2 Downlink 1	5 dB	
Att.1 Downlink 2	5 dB	
Att.2 Downlink 2	5 dB	
Att.1 Uplink common	5 dB	
Att.2 Uplink common	5 dB	
Att. Uplink 1	5 dB	
Att. Uplink 2	5 dB	
RF ON	Yes <input checked="" type="radio"/> No <input type="radio"/> ?	
Subcarrier Tx Power	-10 dBm	?
<input type="button" value="Submit"/>		

Next step is to connect to the remote unit and set it up for test measurement in the uplink.

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RF Strip 1 (Uplink: 824 - 849MHz, Downlink: 869 - 894MHz)

Downlink			
Parameter	Current value:	New value:	Unit:
Gain	65.0	<input type="text"/>	dB
ALC level	43.0	<input type="text"/>	dBm

Set downlink RF on: ☒ or off: ☐

Uplink 1			
Parameter	Current value:	New value:	Unit:
Gain	35.0	<input type="text"/>	dB
ALC level	-13.0	<input type="text"/>	dBm
HW ALC offset	60	<input type="text"/>	-

Set uplink RF on: ☒ or off: ☐

Uplink Testtone			
Parameter	Current value:	New value:	Unit:
Frequency	836.000000	<input type="text"/>	MHz

Set uplink testtone on: ☒ or off: ☐

Submit

Get

In this screen you should also turn RF on, set the gain to about 35 dB as a starting point and then turn on the uplink test tone. Note the frequency of the test tone, this is the frequency you should be measuring on your spectrum analyzer.

Turn on the spectrum analyzer, make sure it is connected to the right port on the right BIU and then find the frequency. A reasonable span is 1 MHz and the receiver band width can be set to 30 kHz or similar. Use the marker to measure the peak of the signal. Then go to the next screen on the remote unit, the RF Status screen.

OBSERVE!

Do not forget to turn of the test tone when you are done with your uplinks. Better check one extra time. They will otherwise interfere with the normal operation of the system by causing noise to the base station.



RF Strip 1 (Uplink: 824 - 849MHz, Downlink: 869 - 894MHz)

RF Status		
Downlink		
Start frequency	Current value:	Unit:
	869.000000	MHz
Stop frequency		894.000000 MHz
RF link		on
ALC threshold		43.0 dBm
Set gain		65.0 dB
Max gain		65.0 dB
Gain		63.6 dB
Output power		43.1 dBm
Uplink 1		
Start frequency	Current value:	Unit:
	824.000000	MHz
Stop frequency		849.000000 MHz
RF link		on
Testtone state		on locked
Testtone frequency		836.000000 MHz
Testtone level		-62.6 dBm
ALC threshold		-13.0 dBm
Set gain		35.0 dB
Max gain		35.0 dB
Gain		35.0 dB
Output power		-27.5 dBm

Reload

Periodic

What we are looking for here is the Testtone Level. Note this down as well, next to the frequency of the test tone you noted earlier.

Then check your spectrum analyzer. Assuming your testtone level is -62,6 dBm as in this example your spectrum analyzer may show -58,2 dBm. Calculating the net gain between the RU and the BIU will then yield $-58,2 - -62,5 = 4,3$ dB. Subtract the coupler between the BIU and the radio base station which in this example was 15 dB and we get -19,3 dB as our net gain.

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We wanted -10 dB so we have 9,3 dB too low gain. We should then increase the gain and the best place to do this would be in the remote unit by setting the gain at $35 + 9,3 = 44,3$ which we will round to 44 dB. That uplink is now finished and we will repeat the settings for all of our uplinks, one at a time.