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BHE Optical Repeaters

(TETRA Master and Slave Repeater Pair)

SOFTWARE USER MANUAL

Technical Documentation

Revision 03

2025-02-26

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Please read this user manual carefully before operating this product.
To ensure proper operation, please read and follow ALL the instructions,
especially the "SAFETY PRECAUTIONS" and "SAFETY INSTRUCTIONS".
Please keep this user manual for future reference.

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DOCUMENT CHANGE RECORD

ISSUE	DATE	MODIFIED BY	REASON FOR CHANGE AND AFFECTED SECTIONS
Rev 01	2024-08-14	Gergely DOBOS	Initial version.
Rev 02	2025-02-19	Gergely DOBOS	Added No Transmission alarm to chapters Alarm Reference and Alarm Settings. Added Tamper description to Slave Common monitored parameters section. Added description of Auto RF State to Slave Common monitored and controlled parameters sections.
Rev 03	2025-02-26	Gergely DOBOS	Added SNMPv3-related chapters (User Management, First-time Setup, Recovery Procedure).

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ACRONYMS

Acronyms used in the manual and their meaning:

AES	Advanced Encryption Standard
ALC	Automatic Level Control
DC	Direct Current
DES	Data Encryption Standard
DHCP	Dynamic Host Configuration Protocol
DL	Downlink
EPN	Equipotential Network
GPRS	General Packet Radio Service
GSM	Global System for Mobile Communications
IP	Internet Protocol
LED	Light Emitting Diode
LNA	Low Noise Amplifier
MD5	Message Digest 5
MIB	Management Information Base
NMS	Network Management System
OID	Object Identifier
PAM	Power Amplifier
PLL	Phase Locked Loop
RF	Radio Frequency
SAW	Surface Acoustic Wave
SHA-1	Secure Hash Algorithm 1
SMS	Short Message Service
SNMP	Simple Network Management Protocol
TCP	Transmission Control Protocol
TETRA	Terrestrial Trunked Radio
UDP	User Datagram Protocol
UL	Uplink
USM	User-based Security Model

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1 MONITORING AND CONTROL

1.1 CONTROL INTERFACES

The master repeater can be controlled in the following way(s):

- Through Ethernet connection using SNMP protocol
- Via RS-232 port
- Packet-switched interface for TCP/IP connection via BHE NMS through 2G/4G modem (optional)

All slave repeaters connected to the master via optical cables can be controlled through the master unit.

The slave repeater can be controlled in two ways:

- Directly through Ethernet connection
- Through the master repeater via optical cable

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1.2 ETHERNET INTERFACE

When SNMPV2/SNMPV3 interface is selected in the initial window of the control program, the program starts to monitor and control the repeater using SNMP protocol. To reach the repeater, the user must enter its IP address and specify the SNMPv3 username, authentication key, authentication type, privacy key and privacy type (in case of SNMPv3), or the read and write community names (in case of SNMP v2).

Each repeater has a factory default and a user default IP address.

After every startup, the device stays reachable on the factory default IP address for a few seconds. After this, the user default IP address and the DHCP setting will determine the IP address of the device. This functionality ensures that even if network settings are set incorrectly, the repeater will not become unreachable. The device will also revert to the factory default IP address for a few seconds if the network cable is unplugged, then plugged in again.

The factory default IP address is calculated as follows:

192.168.1.X where X is: X = 96 + (Serial number) mod 10

In this case, "mod" means the mathematical modulo operation, i.e. the remainder after division.

For example, the last part of the factory default IP address of a master unit with serial number 17 will be 96 + 17 mod 10 = 103.

The user can set the user default IP address to any valid IP. This IP address will be used by the device when DHCP is disabled or no DHCP server is present on the network. The repeaters are shipped with DHCP enabled. Both the user default IP and the DHCP setting can be modified via SNMP.

BHE also provides a Product Finder application that detects BHE devices that are directly connected to the Ethernet network. The program lists the detected devices with their type, serial number and MAC address displayed. The Product Finder uses UDP broadcast messages to find devices on the network. Since routers usually filter out these messages, the program might not find devices that are reachable through a router from the computer running the program. It is possible to prevent a device from answering Product Finder messages, using the control software (see chapter Network Settings).

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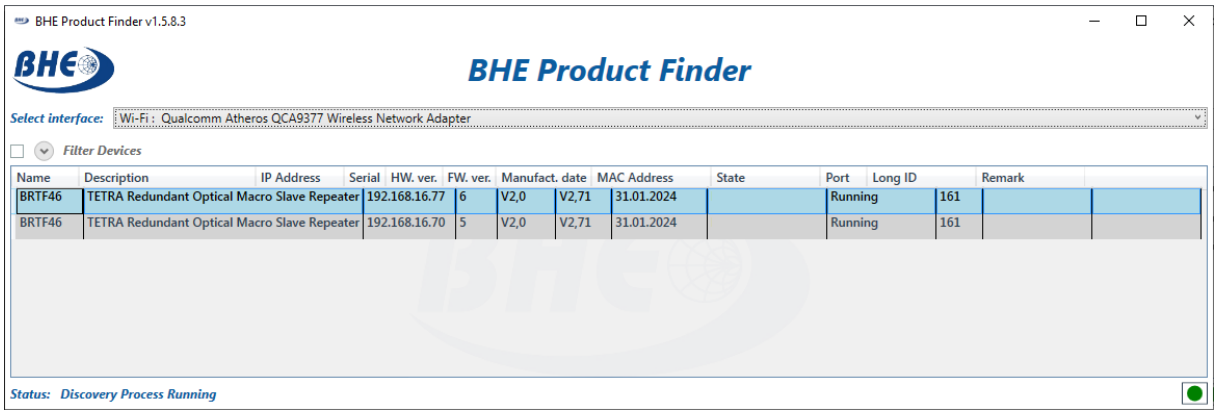

The following ports are used by the device:

- UDP port 161 for general SNMP communication.
- UDP port 162 for SNMP traps.
- UDP port 38142 to answer BHE Product Finder discovery messages.
- UDP port 5100 for firmware upgrades.

1.3 SNMP OPERATION

1.3.1 GENERAL CONSIDERATIONS

The repeater uses SNMPv1, SNMPv2c or optionally SNMPv3 protocol for communication (UDP port 161 for reads and writes and UDP port 162 for trap sending). The minimum protocol version number that the device will accept can be configured by the user. Queries with a lower protocol version number than the configured value will be ignored by the device.

In case of SNMPv2, parameters can be monitored and changed by accessing SNMP objects with the correct community names. The factory default read community names are: **public** or **read**. The factory default write community names are: **private** or **write**. It is strongly recommended to change these values if using SNMPv2.

In case of SNMPv3, parameters can be monitored and changed by accessing SNMP objects with a valid username and password. For more information about user management, see section User Management.

When controlling through MIB browser the appropriate MIB file should be loaded in the browser. Requesting an object that does not exist in the repeater system will result in an “SNMP No Such Object” answer.

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Traps are sent in v2c or v3 format. The user can select which protocol version is used. The community name/username of the traps and the IP addresses of the managers can be set via MIB browser.

By sending asynchronous traps, the agent can alert managers about malfunctions. Waiting till the manager reads the faulty values (e.g. by periodic polling) may not be permitted, as this might take a long time. Meanwhile trap messages can be sent by the device to alert managers of any error immediately. Note that reception of trap messages is not guaranteed.

The repeater can send traps not only in case of failure but also during normal operation. These periodic traps are called heartbeat traps. Trap message sending interval for both the heartbeat and alarm traps can be configured through the MIB browser, as well as the control program. For more information about trap sending, see section Alarm Reporting.

1.3.2 USER MANAGEMENT

The repeaters support SNMP protocol versions v1, v2c and v3. SNMP v3 offers authentication and encryption functionality, providing secure access to devices. The devices implement the User-based Security Model (USM). For a detailed description of USM, see RFC 3414 by the Internet Society.

When using SNMP v3, the device will only accept queries that use a valid username that was previously saved in the device, as well as the correct authentication and optionally encryption passwords. These parameters, as well as several others, define a user who can access the device.

Each user has an associated authentication and encryption algorithm. The repeaters support SHA-1 authentication, and optional AES encryption. Note that MD5 authentication and DES encryption are not supported, as these algorithms are known to be insecure.

Every user also has a status associated with them. This parameter can take the following values:

- active
- not in service
- not ready

If a user's status is "active" it is allowed to access the device. A "not in service" status means that the user is not allowed to access the device. A user is moved from "active" to "not in service" status when a disable command is sent to the device for that user. The reverse happens when an enable command is sent. There is also a third status used during user creation, "not ready", which means that the user has been successfully created, but not all necessary parameters have been set yet. Once all necessary parameters have been set the status changes to "not in service".

Each user also has a storage type. This parameter is managed automatically by the device and can take the following values:

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- volatile
- non-volatile
- permanent

Volatile storage type means that user data is stored in volatile memory and is lost if the device is restarted. All newly created users have this storage type until all parameters required for user creation are set. Once these parameters are set, the device moves all user data associated with the new user to non-volatile storage. Users with non-volatile storage are kept even if the device is restarted. Users with permanent storage cannot be deleted but can be modified, that is, they can be enabled or disabled, and their passwords and privilege level can be changed.

Each user possesses a privilege level. This determines the level of access they have to the device. This parameter can take the following values:

- none
- read-only
- write-only
- read-write
- admin

Users with "none" privilege level are not allowed to access any parameters. Users with read-only privilege can only read parameters. Users with write-only privilege can only write parameters. Users with read-write privilege can both read and write parameters. There are some variables that are reserved for admin level users, so users with only read-write privilege cannot access them. Admin users have read and write access to all user-controllable parameters of the device. At least one admin user must be present in the user configuration, otherwise, it would not be possible to change settings restricted to admin level users. To ensure that an admin user is always present in the system, the device will not execute operations that would result in a system without admin users. For example, it is not possible to disable or delete the last admin user.

The following parameters require admin level access:

- Trap settings
- User management parameters
- Network settings
- Minimum SNMP protocol version and trap protocol version

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- Read and write community names (only applicable if SNMPv2 is enabled)

The factory default user configuration includes two template users. These users have permanent storage type; therefore, they cannot be deleted but their parameters (passwords, privilege level and status) can be changed. The factory default users can be used to initially access the device and perform the necessary configuration. Note that while the factory default user settings are present in the device, parameters can be monitored, but not changed. To enable write access the first-time setup procedure must be completed. For more information about this, see section First-time Setup.

The two template users have the following parameters:

- First factory default user
  - username: sha1-aes
  - authentication protocol: SHA1
  - authentication key: defaultKey
  - privacy protocol: AES
  - privacy key: defaultKey
  - storage: permanent
  - privilege: admin
  - status: active
- Second factory default user
  - username: sha1-NoPriv
  - authentication protocol: SHA1
  - authentication key: defaultKey
  - privacy protocol: None
  - privacy key: N/A
  - storage: permanent
  - privilege: read-write
  - status: active

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These users are called template users due to how new users can be created. To create a new user, an active user must be selected first. When the user creation command is issued to the device, all parameters of the selected user (not including username and privilege level) will be copied to the new user. The storage type of the new user will be volatile and its status will be "not ready", indicating that the user has been successfully created, but not all required parameters have been set yet. To move the user to non-volatile storage and into "not in service" state, the authentication and encryption passwords (if used) need to be changed.

The original passwords must be known in order to successfully set the new passwords. The original password of the newly created user is the same as the selected template user's password.

Once the new user is in "not is service" status, it can be enabled by issuing an enable command. The new user can be used immediately afterwards. New users always start with read-only privilege level. This can be changed after creation, if necessary. The repeaters support up to 4 users besides the 2 permanent template users (which can also be used).

1.3.3 FIRST-TIME SETUP

The factory default user configuration does not provide a secure way to access the repeater. The default authentication and privacy passwords are the same for all devices. If repeaters were left at the factory default settings, an attacker would only need to find out a single (easy to guess) password to compromise potentially many devices.

To ensure that a device with unsecure user settings cannot be put into operation, parameters can only be monitored but not changed while the device still has its factory default user configuration. To enable write access to parameters, it is necessary to perform the first-time setup procedure.

Once first-time setup has been completed, only the buyer is able to access the device.

First-time setup can be performed in different ways depending on user preference. The only requirements are that at the end of the procedure, at least one user with admin privilege exists, and that the password of this user is only known by the buyer. Examples of how to achieve this are listed below.

a) Example 1 – Creating a new admin user and disabling template users

    1) Create a new user by using the "clone" operation on one of the predefined template users. Note that creating a new user can only be done by an admin user, and at this point in the procedure, the only admin user is the first template user (username: sha1-aes). Authentication and privacy parameters are copied from the selected template user. This includes the authentication and privacy protocols, as well as passwords. The

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storage type of the new user will be "volatile" and its status will be "not ready". Its privilege level is "read-only".

2) Change the authentication password of the newly created user. To successfully change the password, both the old and new passwords must be given. The old password of the new user is the same as the password of the template user.

3) Change the privacy password of the newly created user. To successfully change the password, both the old and new passwords must be given. The old password of the new user is the same as the password of the template user.

4) The status of the newly created user changes to "not is service" and its storage type changes to "non-volatile".

5) Activate the new user by issuing an "enable" command. The status of the new user changes to "active".

6) It is recommended to try to access the device with the new user now, to test that the passwords have been set correctly. Issue an SNMP GET query with the new user to any variable that does not require admin access.

7) Change the privilege level of the new user to "admin". Note that this can only be done by an admin user, and at this point in the procedure, the only admin user is the first template user (username: sha1-aes).

8) Disable both template users. First-time setup is complete once this step is done.

b) Example 2 – Changing the passwords of the template users

1) Change the authentication password of the first template user (username: sha1-aes). Note that changing user passwords can only be done by an admin user, and at this point in the procedure, the only admin user is the first template user (username: sha1-aes).

2) Change the privacy password of the first template user (username: sha1-aes). Note that changing user passwords can only be done by an admin user, and at this point in the procedure, the only admin user is the first template user (username: sha1-aes).

3) Change the authentication password of the second template user (username: sha1-NoPriv). First-time setup is complete once this step is done.

There are several alternative ways of completing the first-time setup. For example, at step 8) of Example 1, the passwords of the template users could be changed, instead of disabling the users. In this case, both template users and the new user remain usable. Similarly, in step 3) of Example 2, the second template user could be disabled, and this would complete the first-time setup as well. The only

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requirements are that at the end of the procedure, only the buyer is able to access the device and that at least one active admin user exists.

The above examples have advantages and disadvantages. Example 2 appears simpler, however, if the admin password is mistyped, the device could become unreachable (see section Recovery Procedure on how to recover from this situation). The advantage of Example 2 is that all 7 possible users can be used, while in case of Example 1, only 5 users will be available.

Note that once the first-time setup has been completed, the device no longer checks if the user settings are the same as the factory defaults. This means that it is possible to return to unsecure settings once the first-time setup is complete (e.g. by enabling the template users without changing their passwords after first-time setup has been completed according to Example 1). It is the responsibility of the user to make sure that the user configuration enables secure access to the device.

General recommendations on security:

- Choose long, difficult to guess passwords. Alphanumeric passwords with special characters should be preferred.
- Access the device with user(s) that use encryption.
- Admin user(s) should always use encryption.
- Do not use the same password in more than one device.
- Do not use the same password for authentication and encryption.

1.3.4 RECOVERY PROCEDURE

If the repeater becomes unreachable due to a forgotten password or wrong user configuration, it is possible to revert the device to the factory default user settings. Contact BHE for instructions on how to perform the recovery procedure. Note that once first-time setup has been completed, BHE is unable to access the device anymore. The recovery procedure requires access to the device in question as well as the participation of both the buyer and BHE.

1.3.5 SNMP CONTROL

The repeater can be controlled using SNMP protocol. To allow this functionality, BHE provides a MIB file that can be imported by software designed for SNMP operations (called MIB browsers). Since the master repeater has the same MIB file as the BRMF37 the SNMP related sections of the manual will always refer to BRMF37.

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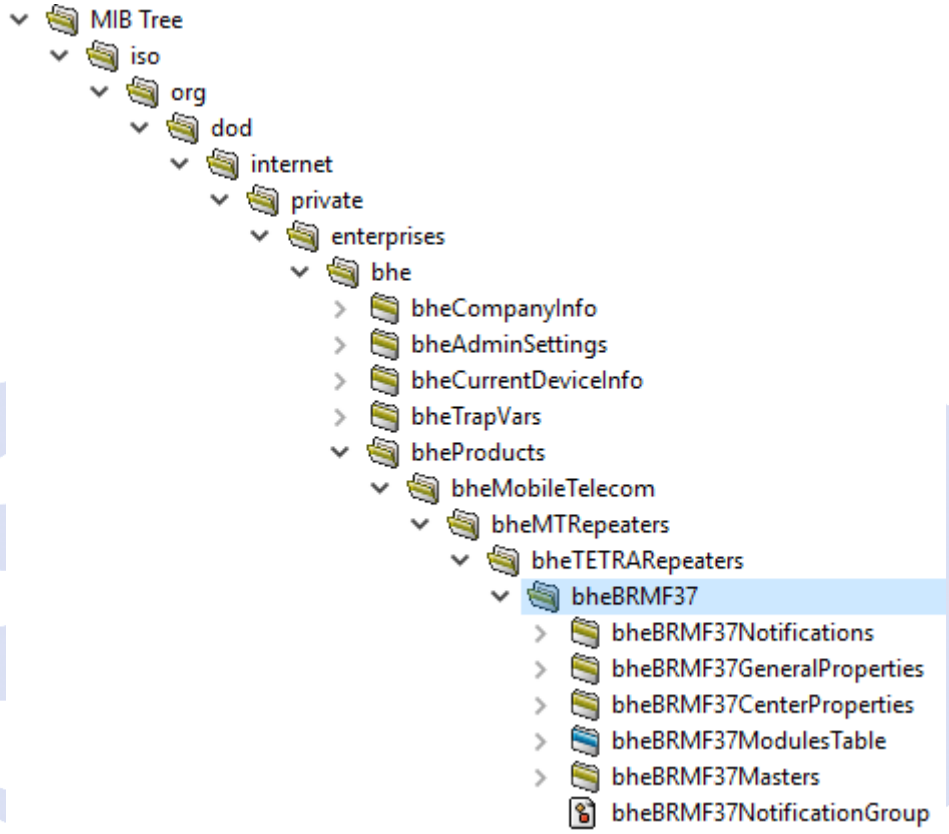
After importing the BRMF37 MIB file, it becomes possible to control the repeater using simple SNMP commands (i.e. “get” command to retrieve the value of parameters and “set” command to set the value of parameters). MIB files can be displayed as a tree of nodes and leaves, where each “leaf” represents a parameter that can be queried and/or set. The BRMF37 MIB tree is shown in the following image, opened to the bheBRMF37 node.



BHE MIB files have two parts: a part common to every BHE MIB file containing common settings as well as general information about the company and the current device, and a device-specific second part. Note that the nodes and OIDs in the common part may change without notice – new parameters may be added or unused parameters may become deprecated.

The common part of BHE MIB files contains the following nodes:

1) bheCompanyInfo
2) bheAdminSettings
3) bheCurrentDeviceInfo
4) bheTrapVars
5) bheProducts

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Leaves in bheCompanyInfo contain general information about BHE, while leaves in bheCurrentDeviceInfo provide information about the current device such as its description, type name and serial number. The bheTrapVars node contains leaves providing an OID for several trap variable bindings. The bheAdminSettings has three child nodes: bheNetworkProperties, bheFactoryCommands and bheModemParamters.

The bheNetworkProperties node contains various network related settings. SNMP settings can also be found here.

The bheCurrentIP leaf returns the current IP address of the device. The bheMACAddress leaf returns the MAC address of the device. The bheDefaultIP, bheIPMask, bheDHCP and bheIPGateway leaves can be used to query and set basic network properties. Note that it is necessary to restart the device for these changes to take effect. The device can be restarted using the bheBRMF37Restart leaf in bheFactoryCommands.

The bheSNMPSettings node contains various SNMP-related properties. Changes to these are saved automatically in non-volatile memory and take effect immediately. The read/write SNMP community names can be set here. The device will only accept read commands that match one of the read community names. The same is true for write commands and write community names. The rest of the leaves in this node concern the trap sending functionality of the device. For more information about these, see the next section.

The bheFactoryCommands node contains the bheBRMF37SetFirmwareUpgradeMode and bheBRMF37Restart leaves. The first can be used to put the device into firmware upgrade mode. After writing to this leaf, the device will restart in bootloader mode and will wait for a new firmware to be downloaded. Note that the network settings of the device remain unchanged during this. After the firmware upgrade, the device restarts automatically with the new firmware.

The device can be restarted using the bheBRMF37Restart leaf in the bheFactoryCommands node.

Leaves in the bheModemParameters node allow configuring and monitoring parameters related to the internal modem. The state of the modem (whether it is registered to the home network), the ID of the cell it is connected to, the RSSI value and other parameters can be monitored. The user can switch between circuit-switched and packet-switched operational modes. The parameters related to these modes (e.g. SMS destination phone number, sending intervals, APN, etc.) can also be configured via this node.

The device specific part of the BRMF37 MIB file can be found under bheProducts ->bheMobileTelecom ->bheMTRepeaters ->bheTETRARepeaters -> bheBRMF37. This node contains five child nodes: bheBRMF37Notifications,bheBRMF37GeneralProperties, bheBRMF37CenterProperties, bheBRMF37Masters and bheBRMF37ModulesTable.

The Notification node contains all trap messages that can be sent by the master unit. The master will monitor the status of all connected devices, and will send trap messages for every status change. A

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specific trap belongs to each connected device. E.g. RF module 1 has its own trap OID, each slave has its own trap OID, etc. For a description of alarm reporting using trap messages, see section Alarm Reporting.

The general properties node contains general information about the master unit of the repeater system, such as its type, serial number, software version number and manufacturing date. The master unit also has three identifier fields that can be set here using the bheBRMF37Iden, bheBRMF37Comment and bheBRMF37NumericId leaves. These are included as varbinds in trap messages. Usage of special characters is not recommended – the Iden and Comment parameters should be short strings containing characters of the English alphabet that identifies the particular master to monitoring personnel (e.g. “Tunnel A Entrance”).

The bheBRMF37CenterProperties node contains information about the center module of the master unit. These include measured parameters, alarm settings (including master external alarms) and commands to refresh and save the system configuration.

Alarm conditions can be monitored using the leaves in the bheBRMF37CenterAlarm node. Here, the bheBRMF37CenterAlarm_Mom leaf contains the momentary alarm states of the master unit. The master unit has 8 possible alarm conditions, including the external alarms. For a description of the individual alarms bits, see the tables at the end of this chapter in section Alarm Reference, or check the description in the MIB file.

The bheBRMF37CenterAlarmLatch field is used during SMS error reporting. If an alarm condition occurs between two SMS messages (that is, an alarm appears then disappears before an SMS message can be sent about it), the alarm will be saved in the latched alarm leaf and the next SMS report will contain it. This ensures that managers will be informed about alarm conditions even if they do not occur continuously, or for long periods.

The bheBRMF37CenterAlarmTrapMask and bheBRMF37CenterAlarmDryContactMask allows setting the trap and dry contact masks of the master unit respectively. The bheBRMF37CenterAlarmDryContactPolarity leaf allows the user to set the dry contact polarity (active open or active closed).

Leaves in the bheBRMF37CenterExternalAlarmTable node allow setting the polarity of external alarms.

The bheBRMF37ModulesTable table contains information about the current system configuration. Each unit in the system has two properties that affect the system configuration: the actual state and the stored state of the unit. The actual state of the unit is "connected" when it is present in the system, "notConnected" when the unit cannot be found. The stored state determines whether the master unit will expect a unit to be present in that position in the system. If the stored state is "stored", the master unit will periodically try to poll the unit for all its monitored parameters. If a unit whose stored state is "stored" becomes unreachable, the master unit will consider that unit lost, and signal a configuration error.

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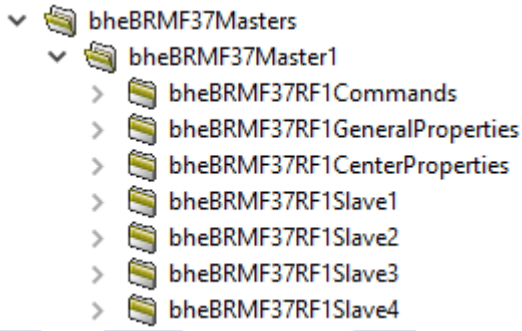
The stored values can be changed by upgrading and saving the system configuration.

For a thorough description of the configuration update process, see the Detected Devices section below.

The bheBRMF37Masters node contains the 8 RF modules that can be present in the system. Each RF module node contains the structure seen on the following image:



In the Commands node, the following commands can be found: save initial values, recall initial values and recall factory values. The Commands node is present in both RF modules and slaves and contains the same leaves. By setting these values, the selected unit will save or recall its initial values, or recall its factory values.

The GeneralProperties node contains general properties of the RF module, similar to the master center unit. Note that individual RF modules in the master unit do not have their own remark field, but the slave units do.

The CenterProperties node contains information about the current state of the RF module (such as temperature, LD and PD values), as well as properties that can be set (such as uplink/downlink gain, downlink AGC).

The Slave1-Slave4 nodes represent the four possible slave units that can be connected to each RF module of the master. All parameters of the slaves are found under these nodes. This is, in effect, the “MIB file” of the slave units.

In the Commands node of the slave unit (e.g. bheBRMF37RF1Slave1Commands) the save/recall initial values and recall factory values commands can be found. The GeneralProperties node contains general information about the selected slave unit (such as its type, serial number and firmware version). The CenterProperties node contains parameters measured in the center module of the slave unit, as well as alarm settings. Other nodes in the slave MIB structure contain various uplink and downlink properties. For a detailed description of these, see the chapter Usage of the Optical repeater control program.

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1.3.6 ALARM REPORTING

The repeater system has the following way(s) of reporting alarms that occur during operation:

- SNMP trap messages (protocol version selectable)
- SMS messages sent by the master unit (if equipped with 2G/4G modem - optional)
- Master-side dry contact relay
- Slave-side dry contact relay
- Front LEDs

Alarm Reporting Using Trap Messages

If the device is connected to the network by Ethernet cable, it can send SNMP trap messages (also called notifications) to managers.

Both the master and slave units can send trap messages. The master unit will send traps for their own alarms (including RF modules, which are located inside the master unit casing) as well as any slave units connected to them. To enable trap sending for a unit, the following steps need to be taken (using a MIB browser - for a description of the same functionality in the control program, see sections SNMP Settings and Alarm Settings):

1) Access the device using a MIB browser. Navigate to node bheAdminSettings->bheNetworkProperties->bheSNMPSettings in the BRMF37 MIB file.
2) Set the IP address of the computer that should receive the traps in the bheTrapAddress leaf of bheTrapTable. Enable trap sending to this address using the bheTrapEnable leaf in the same table. Note that trap messages can be sent up to five different managers. If traps need to be sent to more than one manager, repeat step 2) as necessary.
3) Set the trap sending intervals for failed parameters using leaf bheSNMPSettings->bheTrapIntervalFailed, and for error free operation using leaf bheSNMPSettings->bheTrapIntervalHeartBeat. Enable heartbeat traps (sent when the device has no errors) using the bheSNMPSettings->bheTrapHeartBeatEnable leaf, if needed.
4) Enable trap sending globally using the bheGlobalTrapEnable leaf in bheSNMPSettings.
5) Configure the trap masks for each device.

Alarms in the repeater system are indicated by the various AlarmMom leaves in the MIB file (short for Alarm, Momentary). For example, the momentary alarms of the master unit are indicated by the bheBRMF37->bheBRMF37CenterProperties->bheBRMF37CenterAlarm->bheBRMF37CenterAlarmMom leaf. Each bit in these values indicates a possible alarm in the system. For a description of what sort of error the individual alarm bits of the master, slave and RF module indicate, refer to section Alarm Reference, or see the MIB file.

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To enable trap sending for an alarm, the corresponding trap mask bit must be set to 1. If the value of an alarm trap mask is 0, the system will consider that parameter to be correct when determining what sort of trap message to send.

All traps sent by the master units contain the following information:

- The system uptime (how long the master unit that sent the trap has been running)
- The trap OID (this will be different for every RF module and slave in the system)
- The status of the device. This can take the following values:
  - No alarm continuous (0). The device stayed in “operates correctly” state.
  - Alarm cleared (1). One or more alarms ceased to be present. The device entered “operates correctly” state.
  - Alarm new (2). A new alarm appeared. The device did not have active alarms previously (that is, the device left “operates correctly” state).
  - Alarm changed (3). The device has one or more active alarms, but there was a change in which alarms are active compared to the previous trap message.
  - Alarm unchanged (4). The device has one or more alarms, and there was no change in them. The trap was sent because the failed trap timeout has elapsed.
- Trap identifier. This is a value that is increased whenever a trap message is sent.
- RF module address. The address of the RF module that generated the trap, or the address of the RF module the slave that generated the trap is connected to. If the master unit sends a trap for one of its own alarms, this value is 0. Otherwise, this is an integer value between 1 to 8.
- Slave address. The address of the slave unit that generated the trap. If the master unit or an RF module generated the trap, this value is 0. Otherwise, this is an integer value between 1 to 4.
- RF module connection states. The bits of this integer value indicate the connection states of the RF modules. Bit 0 corresponds to the connection state of the first RF module, Bit 7 corresponds to the connection state of the 8th RF module.
- Slave connection states. The bits of this value indicate the connection states of the slaves. Bit 31 corresponds to the 4th slave connected to the 8th RF module. Bit 30 corresponds to the 3rd slave connected to the 8th RF module. The other bits follow the same pattern, for example the connection state of the 4th slave of the 7th RF module is indicated by Bit 27.
- The trap mask of the module that sent the trap.
- The momentary alarm values of the module that sent the trap.
- System description string. A string that describes all units connected to the master unit, including the type and serial number of the connected modules, and the remark string of slave units. The unit are listed in the same order as they would appear in the System View of the control software. Units are separated by semicolons. This means that the following format is followed:

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RF Module 1; RF1 Slave1; RF1 Slave2; RF1 Slave3; RF1 Slave4;RF Module 2; RF2 Slave1; RF2 Slave2;…

- The type of the master unit that sent the trap message.
- The serial number of the master unit that sent the trap message.
- The remark string of the master unit that sent the trap message.
- The comment string of the master unit that sent the trap message.
- The numeric identifier of the master unit that sent the trap message.

In case of master center traps, the following varbind is also present:

- The names of the external alarms.

In case of RF module traps, the following varbinds are also present:

- The type of the RF module.
- The serial number of the RF module.

In case of slave unit traps, the following varbinds are also present:

- The names of the external alarms of the slave unit.
- The type of the slave that induced trap sending (e.g. BRTF46).
- The serial number of the slave that induced trap sending (e.g. 00005).
- The remark string of the slave that induced trap sending.
- The comment string of the slave that induced trap sending.
- The numeric identifier of the slave that induced trap sending.
- The momentary state of the RF redundancy switch (only applicable in repeaters with redundant optical links).

Note that the trap OID will depend on which unit generated the error.

The master unit will keep sending trap messages as long as an alarm condition is active (and trap sending for that alarm is enabled). Therefore, the manager will receive trap messages at specific intervals while the alarm is active. These intervals can become shorter if an additional alarm appears, or if an alarm condition ceases.

Example:

A master unit has a supply voltage alarm and is configured to send trap messages every 15 seconds. The first external alarm of the master unit becomes active 3 seconds after sending the first alarm trap. Afterwards, both alarms continue to be present. In this case, the following will happen (time elapsed on the left, events on the right):

0s	Master sends trap with VALUE = 00 00 00 20 (supply voltage alarm is active)
0s	Trap timeout is reset (next trap will be sent after 15s)
3s	Master notices that the first external alarm became active

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3s Master sends trap with VALUE = 00 00 00 21 (supply voltage and first external alarm active)

3s Trap timeout is reset (next trap will be sent after 15s)

18s Master sends trap with VALUE = 00 00 00 21 (supply voltage and first external alarm active)

Monitoring BHE Devices in Practice

There are two main ways of monitoring any SNMP-capable device: periodically polling device status, or relying on asynchronous trap messages sent by the devices. Both approaches can work equally well with BHE devices.

The simplest way to monitor the status of each device through polling is to query its so-called AlarmMom (short for "Alarm, momentary") parameter. Every BHE device possesses a parameter like this, including slave devices in optical systems. The integer value returned when this parameter is queried should be interpreted as a bit string, with each bit corresponding to a possible alarm source in the device. For a description of the individual alarm bits, see chapter Alarm Reference.

All parameters of all slave units can be retrieved from the master unit. Each slave unit has its own corresponding part in the MIB file. However, when slaves are monitored through the master unit, the master needs to query the slave parameters through the optical network. If internal communication is interrupted and a slave becomes unreachable (e.g. due to too high optical loss between the master and slave), the master unit will indicate a configuration error. When the parameter of a lost slave unit is queried over SNMP, the master unit will return the value it received from the slave when it was last reachable. To find out which device in the system is lost, the bheBRMF37ModulesTable can be queried, which shows the status of all devices in the system.

Monitoring the optical repeater system is also possible by enabling asynchronous trap signalling in the master unit. In this case, the master unit will send a separate trap message with a specific OID for each connected device. A new trap is sent as soon as possible when the alarms of any device in the system change. Otherwise, the two trap timeouts (failed and heartbeat intervals) determine when trap messages will be sent.

When trap-based monitoring is used, the status of all connected devices in the system can be retrieved from the trap varbinds. The RF module and Slave connection state varbinds are especially useful for this, as well as the system description string.

1.3.7 INTEGRATION WITH NETWORK MANAGEMENT SYSTEMS

SNMP capable repeaters manufactured by BHE work out of the box with BHE NMS, the network management system developed by BHE.

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BHE NMS provides the following features:

- Client/server architecture
    - Several clients can observe the system at the same time
- Status monitoring via different interfaces
    - SNMP monitoring
    - SMS reception using a GSM modem
    - GPRS connection using a GSM modem
- Repeater control via different interfaces
    - SNMP control
    - TCP/IP control
    - CSD call using a GSM modem
    - GPRS connection using a GSM modem
- Processing of SNMP traps and SMS monitoring messages
- Automatic alarm notifications through e-mail
- Repeater database, which contains the entire system configuration
- Automatic recognition of devices (provided the devices are configured correctly)
    - New devices are added to the NMS automatically
- SNMP trap and SMS history
- Location view where devices are shown on actual maps
- Searching and filtering for data
- User management
- Activity log
- Support of remote client software via SNMP, CSD or TCP/IP connection
- Automatic database backups

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- Several different ways of showing alarms that allow determining the state of the system at a glance
- Grouping of devices

For more information on BHE NMS refer to the NMS manual document.

For compatibility with other network management systems, BHE provides an SNMP MIB file for the repeater system. By importing the MIB file other network managers can monitor BHE devices.

Generally, either the trap messages from the repeaters need to be processed by the manager, or the manager must periodically poll all the relevant parameters of the system. Since different managers may use very different ways of specifying which parameters should be monitored for a device, or how traps should be decoded, BHE cannot support all network managers outright.

Support might be conditionally provided for different network managers on user request.

1.3.8 ALARM REFERENCE

Each device (master unit, RF modules and slave units) in the repeater system has its own alarm conditions. These can be monitored by querying the AlarmMom parameters in the MIB file that correspond to the specific device. For example, the alarms of the master unit can be viewed by issuing an SNMP GET request to the bheBRMF37CenterAlarmMom leaf in the bheBRMF37CenterAlarm node (OID: .1.3.6.1.4.1.38142.5.1.1.1.10.2.9.1). The alarms of the RF module can be found on leaf bheBRMF37RFxAlarmMom (OID: .1.3.6.1.4.1.38142.5.1.1.1.10.4.x.3.20.1.0), where x is replaced by the address of the RF module in the master unit. The alarms of the slave can be found on leaf bheBRMF37RFxSlaveyAlarmMom (OID: .1.3.6.1.4.1.38142.5.1.1.1.10.4.x.(3+y).3.11.1), where x is replaced by the address of the RF module in the master unit, and y is replaced by the address of the slave in the RF module.

Master Alarms

BIT0	External Alarm 1
BIT1	External Alarm 2
BIT2	External Alarm 3
BIT3	External Alarm 4
BIT4	Tamper (not used)
BIT5	Center voltage

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BIT6	Master current
BIT7	Config Error
BIT8	Modem Error (optional)
BIT9	Error Log Full (optional)
BIT10	Supply Voltage, Input B (optional)

RF Module Alarms

BIT0	Temperature
BIT1	LD Alarm
BIT2	PD Alarm
BIT3	Downlink Forward Power

Slave Alarms

BIT0	Uplink Overdrive Over 30 Min.
BIT1	Reserved (always 0)
BIT2	Uplink Module Current
BIT3	Downlink Overdrive Over 30 Min.
BIT4	Downlink Overpower
BIT5	Downlink VSWR
BIT6	PAM Over Temperature
BIT7	Downlink PAM Current
BIT8	Module Temperature
BIT9	Center Supply +12V
BIT10	Fan error

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BIT11	Tamper (some devices)
BIT12	External Alarm 1
BIT13	External Alarm 2
BIT14	External Alarm 3
BIT15	External Alarm 4
BIT16	LD Level (Link A)
BIT17	LD Alarm (Link A)
BIT18	PD Level (Link A)
BIT19	PD Alarm (Link A)
BIT20	RSSI (Link A)
BIT21	LD Level (Link B)
BIT22	LD Alarm (Link B)
BIT23	PD Level (Link B)
BIT24	PD Alarm (Link B)
BIT25	RSSI (Link B)
BIT26	Reserved (always 0)
BIT27	Uplink Momentary Overdrive
BIT28	Downlink Momentary Overdrive
BIT29	Reserved (always 0)
BIT30	Optical Loss (only available when accessed through the master unit)
BIT31	No Transmission

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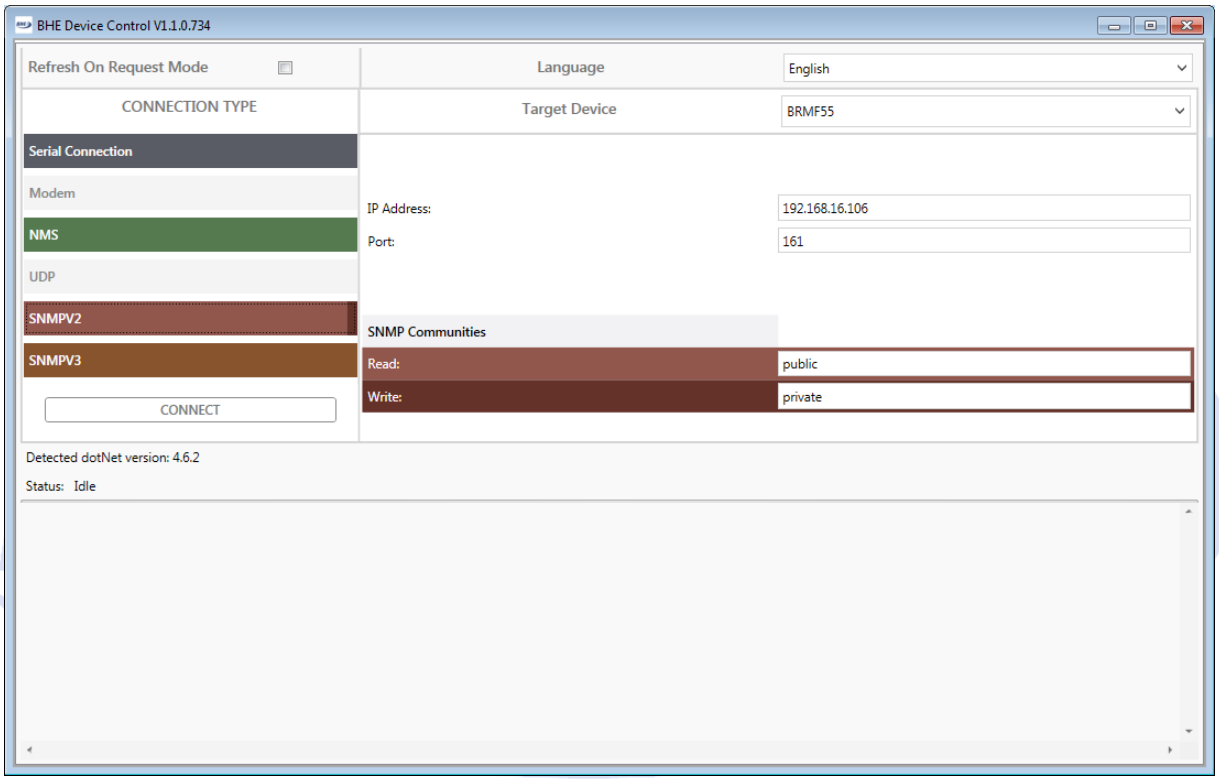
1.4 USAGE OF THE CONTROL SOFTWARE

1.4.1 STARTING THE PROGRAM

The interface through which the software is connected to the repeater has to be selected first at start of the control program.



Since the program was written to control many types of BHE manufactured optical repeaters the startup window offers various possibilities for the connection:

- Serial Connection: Connection to a repeater through RS232 serial port.
- Modem: Connection to a repeater through CSD call. Optional in the master unit.
- NMS: Connection to a repeater through the embedded 4G modem. Note that BHE NMS Server is required to connect to the device through 4G connection. Optional in the master unit.
- SNMPV2: Connection to a repeater through SNMPv2 protocol. Available by default in both master and slave units.

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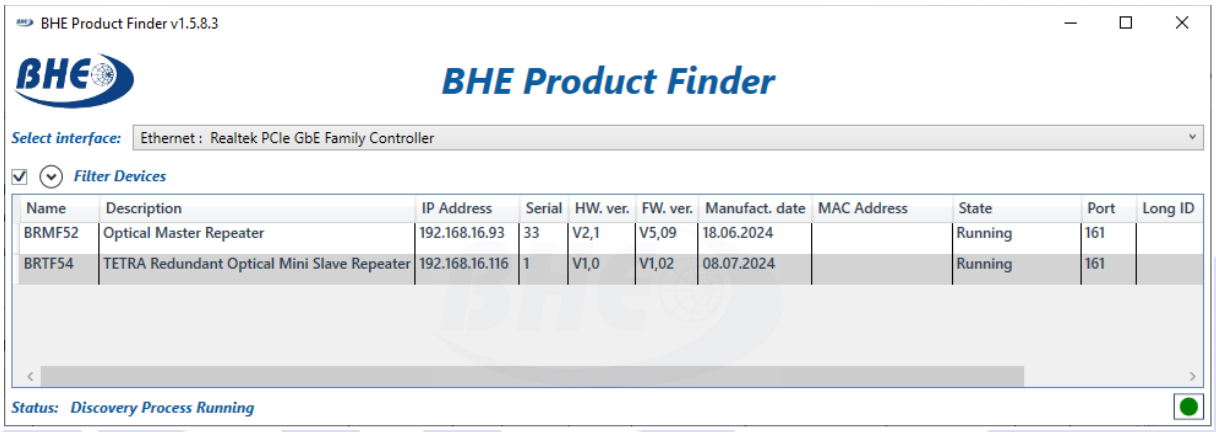
- SNMPV3: Connection to a repeater through SNMPv3 protocol. Optionally available for both master and slave units.

When selecting SNMPv2control, the user should enter the values of the Read and Write communities which are “read” and “write” by default in the repeaters.

When selecting SNMPv3 control, the user should enter the authentication and privacy parameters of the user that should be used to control the device.

The IP address can be determined using the BHE Product Finder program which detects and lists BHE devices connected to the Ethernet network.



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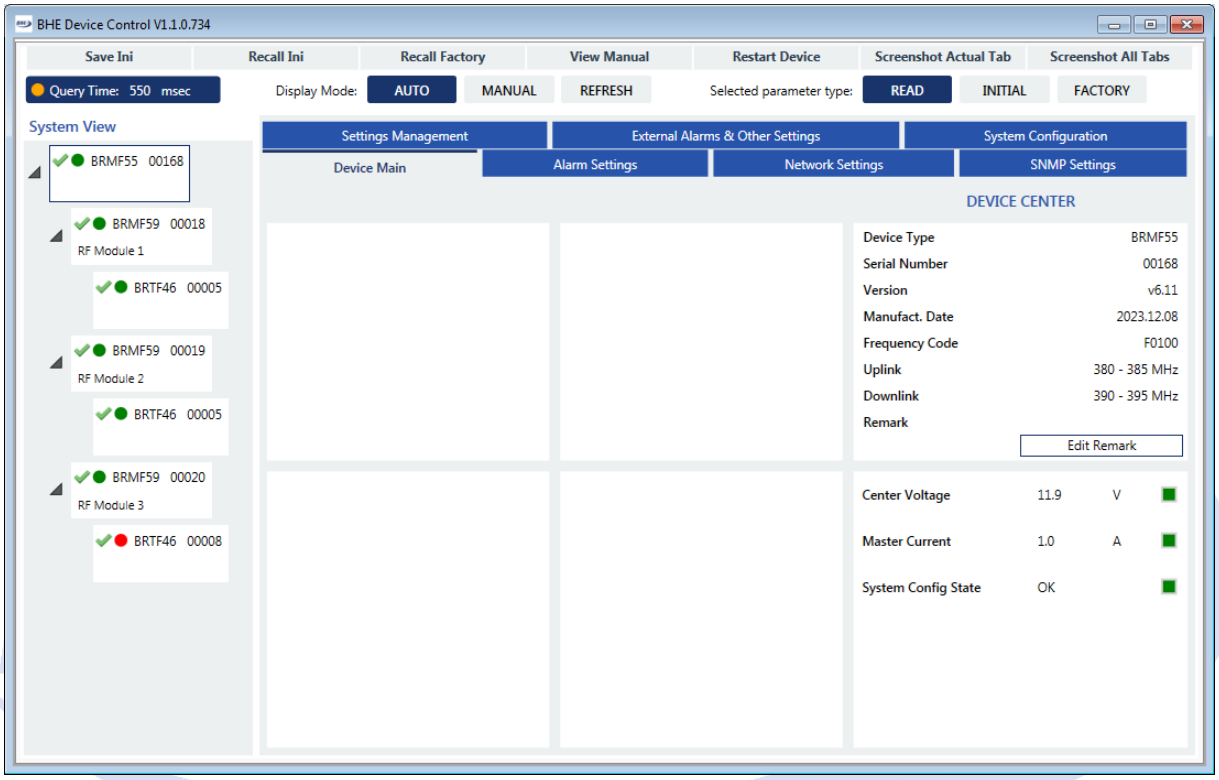
1.4.2 OVERVIEW OF THE MAIN WINDOW

After establishing the connection to the repeater the main window appears on the screen.



The main window consists of the following parts: menu buttons, display mode settings, parameter type selection, the list of tabs containing the device parameters and, in case master units a tree view that shows all devices connected to the master unit.

Some device parameters can only be monitored, while others can also be changed. There are two kinds of settable parameters: those that are saved immediately and those that are only saved when a specific 'save' command is issued to the device.

Parameters that are saved immediately have two values associated with them: the current user setting and the value read back from the device.

Parameters that are saved on command have four values associated with them: the current user setting (displayed under the 'SET' column); the momentary value read back from the device (displayed under the 'READ' column); the initial value (displayed under the 'INI' column); and the factory default value (displayed under the 'FACTORY' column). Initial values are loaded on startup, meaning that after a reset, the momentary values will be equal to the initial values. Momentary values can be saved as

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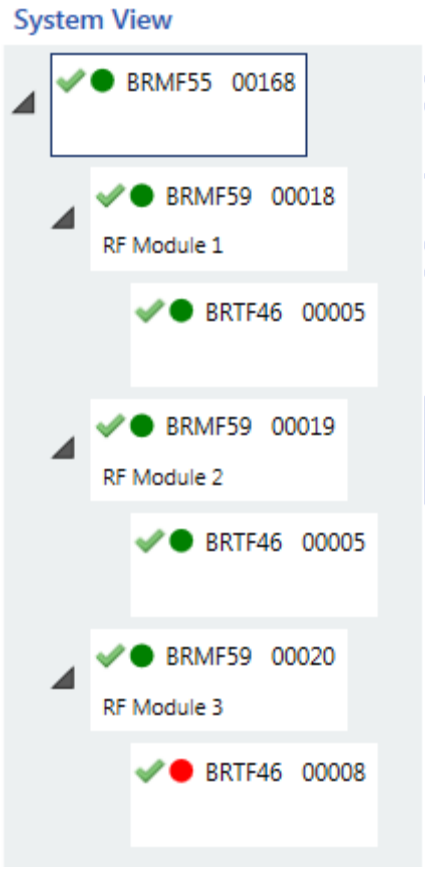
initial by sending a save command to the device. Initial values can be recalled by sending a recall initial values command to the device. Factory values can be recalled by sending a recall factory values command to the device.

The control program uses a two-column display scheme: user settings are always displayed under the 'SET' column. The contents of the second column are selected by the user: the read, initial or factory values can be displayed.

The main window consists of the following groups:

- System View– The left part of the screen displays the structure of the repeater system accessed: the master repeater with its RF modules and the slave repeaters connected to the master via optical cables. A small circle near each unit indicates the state of the unit, giving a quick alert to the user in case of repeater malfunction.



- Tab bar – Shows the different parameter groups present in the device. The middle and right parts of the screen will show parameters belonging to the selected group.

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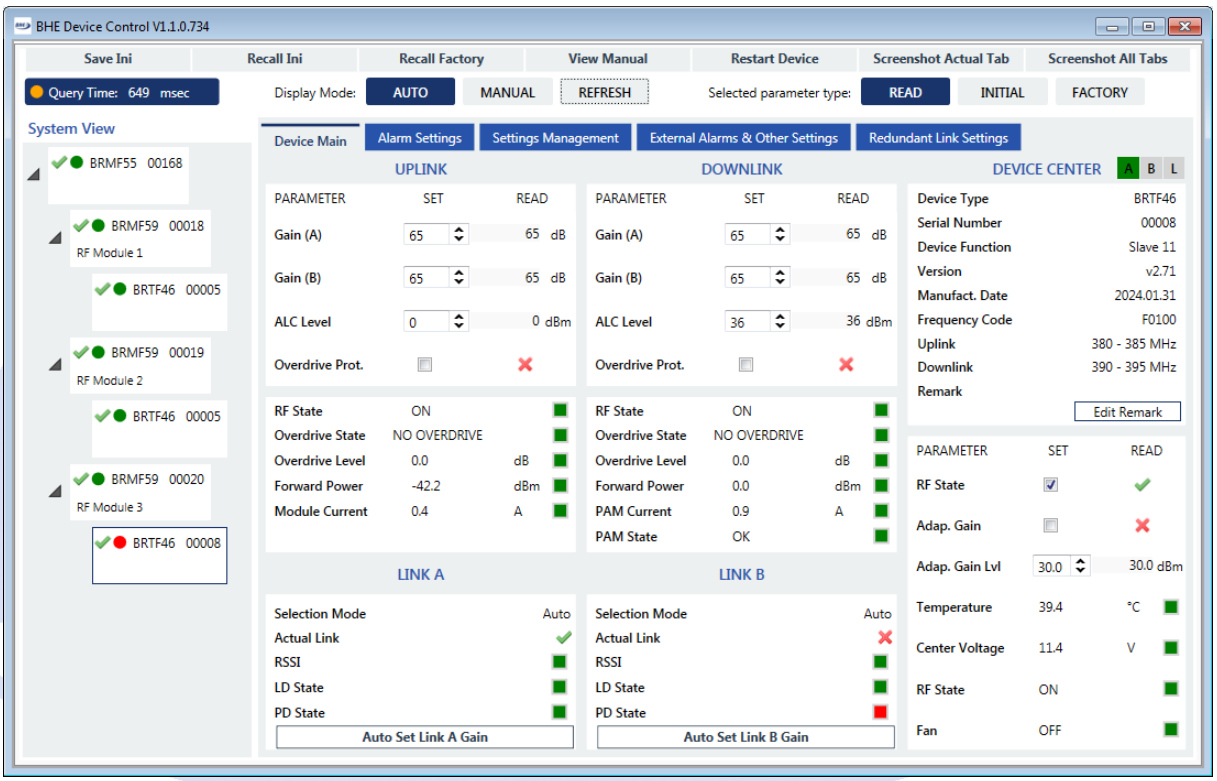
- Device parameters – The middle and right parts of the screen display the monitored and controlled parameters of the device selected in the System View. Monitored parameters within normal operating range have a green square near them while parameters out of normal operating range have a red colored square.



- Button bar – Contains miscellaneous functions: Recalling/saving initial values, taking screenshots, selecting the display mode and the type of shown parameters.

  - Save Ini: The momentary (READ) values of the controlled parameters will be saved as INI (initial) values.
  - Recall Ini: Controlled parameters will be set to values that were previously saved as initial values.
  - Recall Factory: The controlled parameters will be set to values that were set in the factory during manufacturing.

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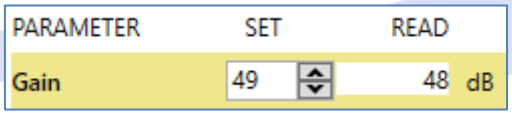
- View Manual: View the user manual of the currently selected device.
- Restart Device: Restart the device that is currently selected in the System View. Note that RF transmission is interrupted for a few seconds when a slave unit is restarted. The control software will warn the user of this and ask for confirmation before restarting the slave.
- Screenshot Actual Tab: Saves a screenshot of the program as it appears.
- Screenshot All Tabs: Saves screenshots of each tab in a .docx file.

- Display mode settings

- Auto mode: The 'SET' and 'READ' values are automatically synchronized after 4 query cycles. If there is discrepancy between values, the user setting ('SET' value) will be overwritten by the value read back from the device ('READ' value). Before this happens, the parameter value in question is highlighted in yellow, as in the following image.



- Manual mode: The 'SET' and 'READ' values are not synchronized automatically. Differences between 'SET' and 'READ' values are highlighted in yellow.
- Refresh: Immediately perform synchronization of the 'SET' and 'READ' values.

- Selected parameter type

- READ: The second column in the device main tab displays the values read back from the device.

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- INITIAL: The second column in the device main tab displays the initial values.
- FACTORY: The second column in the device main tab displays the factory default values.

1.4.3 SYSTEM VIEW

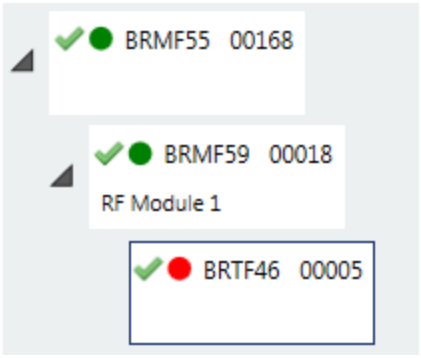
The System View shows the structure of the repeater system controlled through the software.

The appearance of this structure depends on the type of repeater that is accessed. Both the master and slave repeaters have an Ethernet interface and can be directly accessed by the program.

If a slave repeater is accessed through Ethernet, the System View will not be visible. No other slaves, and neither the master connected to this slave by optical cable can be controlled by the program. Only the current slave is available, and its parameters will be displayed in the middle of the screen.

If a master repeater is accessed through Ethernet, the System View will show the master repeater with its RF modules and all the slave repeaters connected to the master by optical cables. Both the master and the connected slaves can be controlled by the program.

The system appears in the following 3 level tree structure:



First level	The accessed master repeater	
Second level	RF module 1…8	The RF modules built into the master. A maximum of 8 RF modules are supported per master unit.
Third level	Slave device 1…4	Slave repeaters installed on an RF module. A maximum of 4 slaves are supported per RF module.

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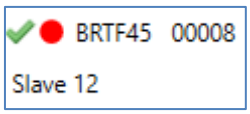
The second line in each tree element shows the remark string of that device. Since RF modules do not have a remark string, their position in the system configuration is shown instead (e.g. RF Module 1 means the 1st RF module in the master unit). If the remark string of the slave unit is empty, the address of the slave is shown in the second line instead of the remark string, as in the following image:



The first digit of the slave address indicates which RF module the slave is attached to (e.g. the above slave is connected to the 1st RF module). The second digit indicates the optical wavelength of the slave. It is important to note that slaves with the same wavelength are not allowed to be installed on the same RF module (see Installation Instructions). Installing slaves with the same wavelength on the same RF module will cause incorrect system operation due to communication collision. Different RF modules may have slaves with the same wavelength.

Slaves are manufactured with 4 different wavelengths; therefore, a maximum of 4 slaves can be connected to a single RF module.

By clicking on a unit in the structure, it can be selected for detailed control and monitoring, and its parameters will appear in the middle and right parts of the screen.

Each unit in the system has two small icons in their tree element. The first icon indicates the state of that device in the system configuration. This icon can take the following shapes:

Icon	Meaning
✔	Normal, OK. Device has been saved in the system configuration and is currently present in the system. This is the normal, expected state of a device.
✖	Lost. The device is stored in the configuration, but is currently not reachable.
✚	New. Device has been found during configuration update, but has not been stored yet.

The second icon indicates the alarm status of the device. This circular icon can take the following colors:

Icon	Meaning
●	Normal, OK. Device operates correctly, without any alarms.
●	Alarm. Device has one or more active alarms.

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	Unknown. Alarm status for this device is not available (because e.g. the device is lost).

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1.4.4 SYSTEM CONFIGURATION

The desired configuration accepted by the user is always stored in the master repeater. All units in this stored configuration are continuously polled by the master (this is why a disconnected repeater is automatically detected and is displayed as lost). If a master RF module is lost, its slaves will become lost too. Lost units cause configuration error in the master unit. Units not in the stored configuration are not automatically polled.

The control software provides a way to modify the system configuration both automatically and manually. This is done on the System Configuration tab, where all possible RF modules and slaves in the system are shown in tabular format.

Each RF module is shown in the left-most column. To the right of the RF module, the four possible slave units that can be connected to it are visible. Two slaves are shown on each line (slaves 1 and 2 on the first line, slaves 3 and 4 on the second line).

Two parameters are shown for each RF module:

1) The number of internal communication packets that have been sent to the module (in the Packets Sent line).

2) The number of internal communication packets for which no response came from the module (in the Packets Lost line). In parentheses next to the Packets Lost value, the packet loss percentage calculated from these two parameters is also shown.

Four parameters are shown for each slave unit:

1) The remark string of the device.

2) The number of internal communication packets that have been sent to the unit (in the Packets Sent line).

3) The number of internal communication packets for which no response came from the unit (in the Packets Lost line). In parentheses next to the Packets Lost value, the packet loss percentage calculated from these two parameters is also shown.

4) The optical loss between the master and the given slave unit. This is calculated by the master unit from the LD (laser diode) voltage of the RF module the slave is connected to and the PD (photo diode) voltage of the slave unit. Internal communication (and therefore, monitoring and control through the master unit) is not guaranteed to work if the optical loss exceeds 15 dBo. An alarm is generated in the master unit for each slave whose optical loss is greater than this value (see section Alarm Reference for a list of possible alarms).

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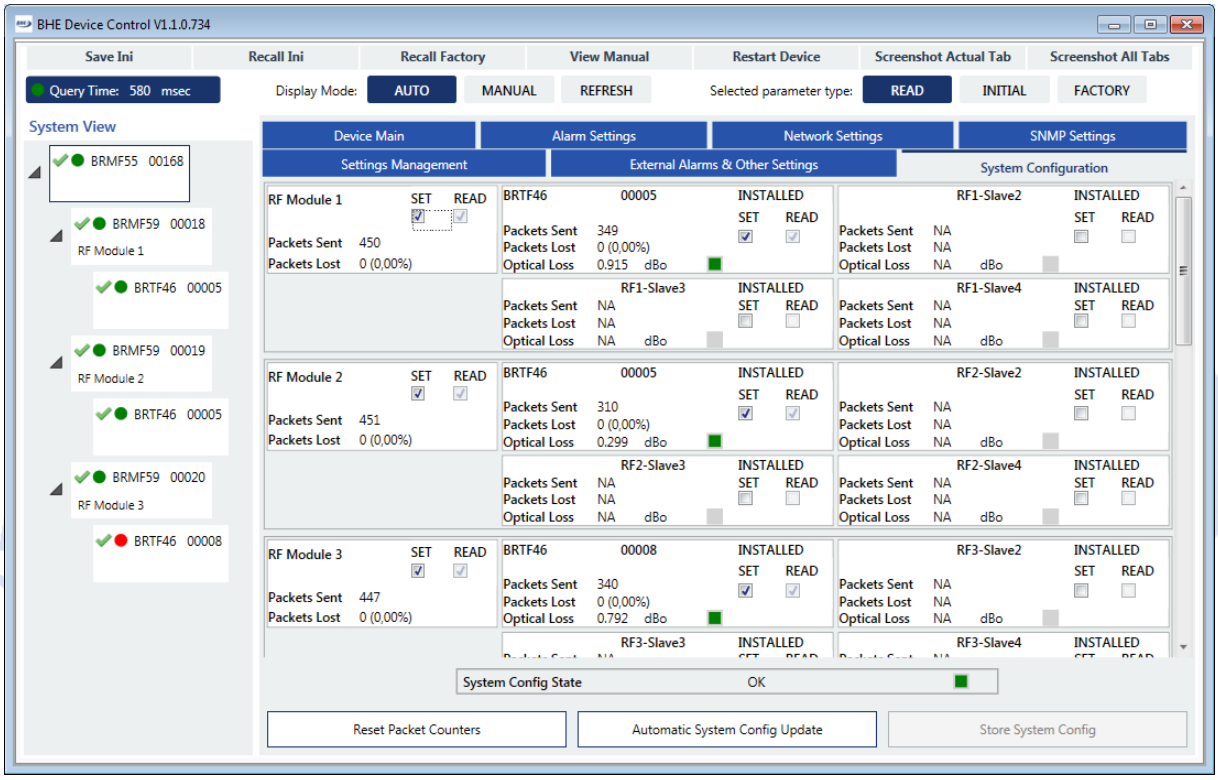
Note that the shown Optical Loss value is only approximate, and can only be calculated when internal communication is possible between the master and slave unit (because the master unit needs to know the slave's PD voltage, which it can only retrieve through internal communication). Therefore, if the optical loss is too high for communication between the master and slave, the displayed value will be based on the last PD voltage value received from the slave. The goal of showing the Optical Loss value is to give the user an indication of the reserves present in the system, not to provide an exact measurement.

The packet counters can be zeroed by clicking the Reset Packet Counters button.



A unit that has been newly added to the system since the configuration was last modified is not automatically detected. Newly connected units should be added to the system either by clicking the Automatic System Config Update button, or manually enabling the checkbox next to them in the System Configuration tab.

After the Automatic System Config Update button is clicked, the master unit enters a special detection state. It is assumed that the Update Config button is clicked because there is a change in the system configuration, so any new or lost devices have been added to or taken out of the system intentionally. The control program will indicate that the configuration is being updated in several places: the System Config State line; at the top of the System Configuration tab; by a red outline in the tab bar; and by disabling all controls.

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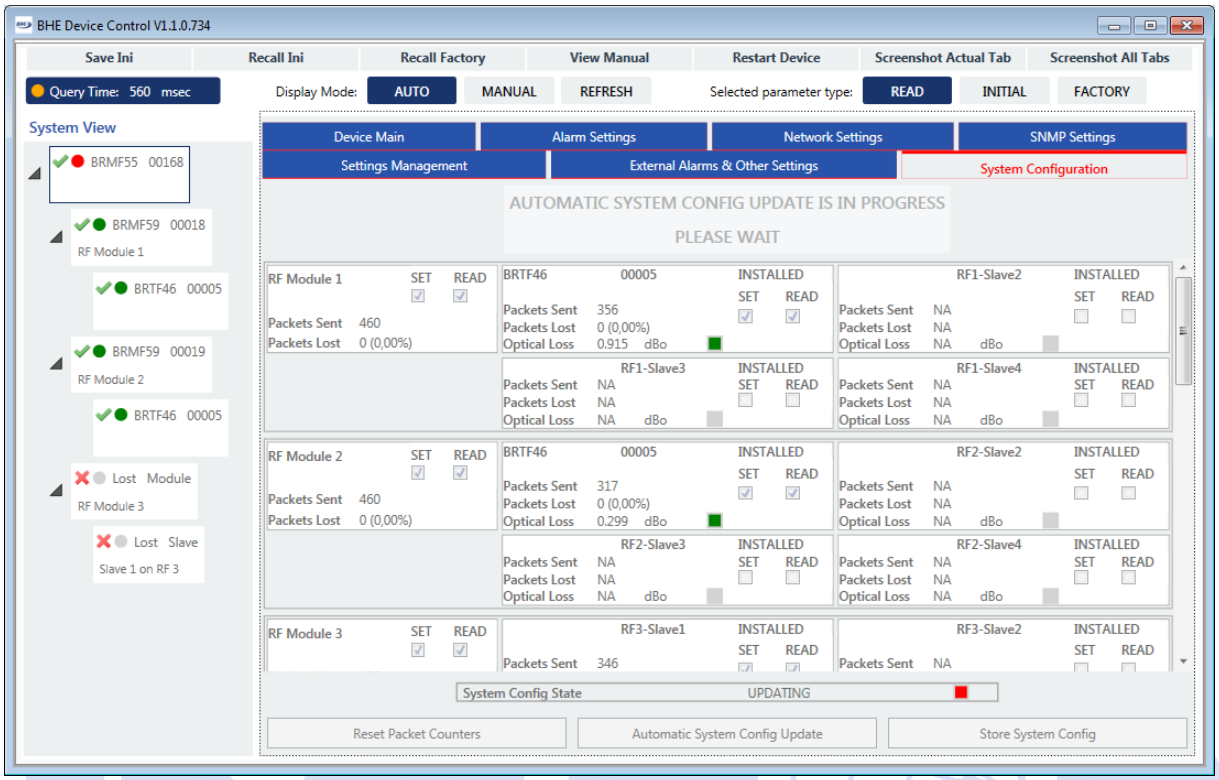

After the Automatic System Config Update button is clicked, the master unit will perform the detection procedure. This might take up to 3 minutes to complete, because the master unit will try to reach every possible device in the system (8 RF Modules and 32 slave units in total). If a device is found that was not present in the system previously, it will be considered "new" in the configuration. If a device that was present cannot be reached during detection, it will be considered "lost". Note that "new" devices can only appear in the system after the Update Config button was clicked.

The configuration shown by the control program can be accepted by clicking the "Store System Config" button. When this button is clicked, the master unit will store the configuration in its non-volatile memory, and will later compare the actual system configuration to this stored configuration. It is only possible to store the system configuration after the master unit has finished its detection procedure. At this time, the System Config State line will show NOT SAVED, as seen in the following image.

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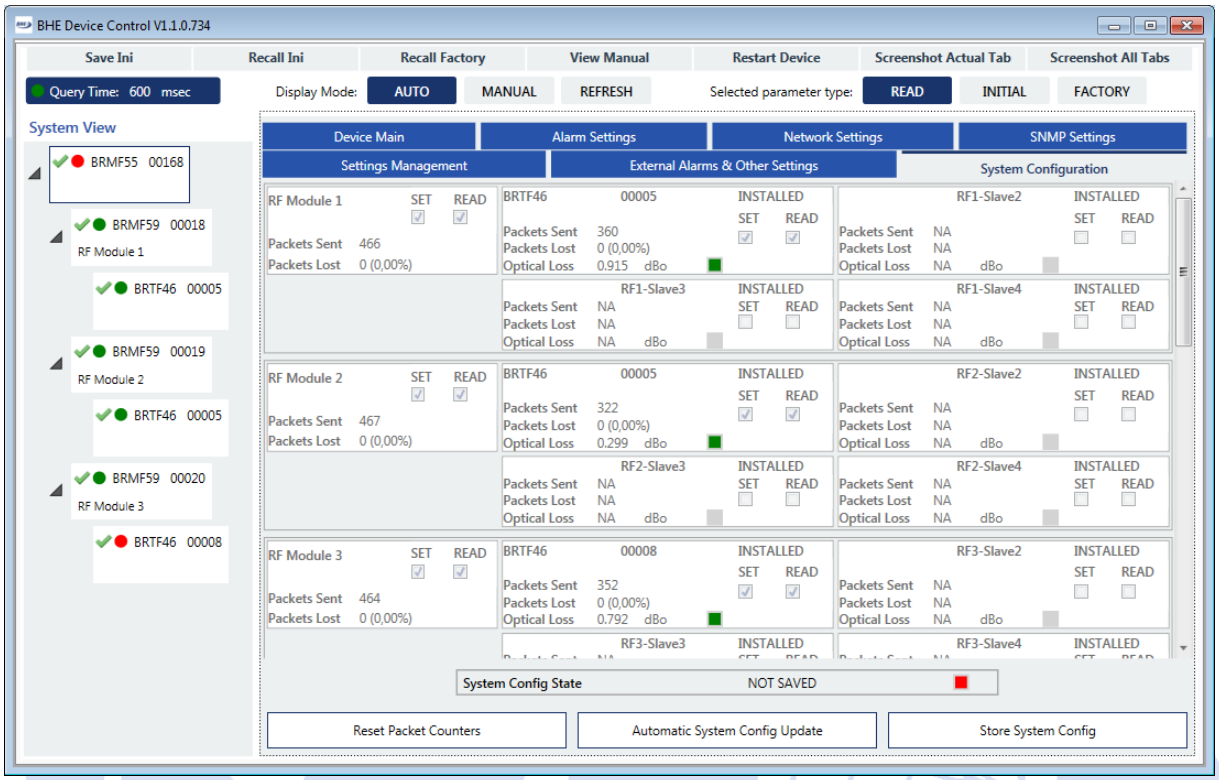

After storing the configuration, the "new" (✚) indicators turn into "normal" state indicators (✔). Lost devices (✘) are removed from the tree. The middle part of the System Configuration tab will also indicate changes in the system by highlighting them in yellow. The yellow highlighting can be made to vanish by clicking the Refresh button in the Button Bar. Note that clicking the Refresh button has no effect on the master unit. It is only used to synchronize user settings and values read back from the device by overwriting the momentary user settings with the read-back values.

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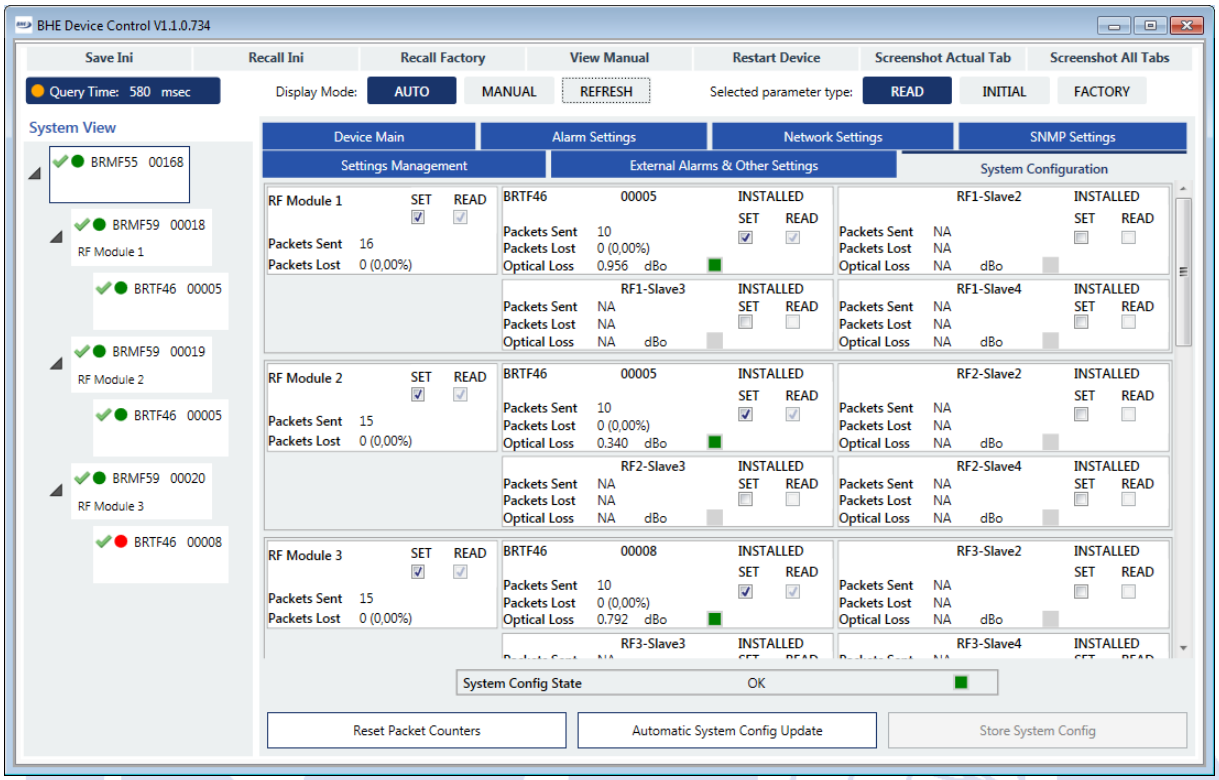

Note that to ensure correct operation, the configuration should always be stored. The master unit should not be left in detection state during normal operation, because this will prevent configuration errors from being correctly indicated and can also lead to lost slave devices. Therefore, if the Automatic System Config Update button is clicked, it should always be followed by clicking the Store System Config button. It is safe to refresh the configuration multiple times before storing it.

After finishing the installation of the optical repeater network, the configuration should be detected by the master using the Automatic System Config Update button and the detected configuration should be stored by pressing the Store System Config button!

It is also possible to manually modify the system configuration. This can be done by simply clicking the checkboxes next to any device. Changes are stored in the master unit immediately. When a device is newly enabled, its parameters will be refreshed by the master and the relevant parts are shown on the screen.
When an RF module is removed from the system configuration, all slaves connected to it will also be removed. However, the slaves need to be added individually after adding an RF module to the system. Note that the master unit settings file saved through the Settings Management tab includes the system configuration. When the saved file is loaded, the system configuration of the master unit will be made to match the one saved in the file.

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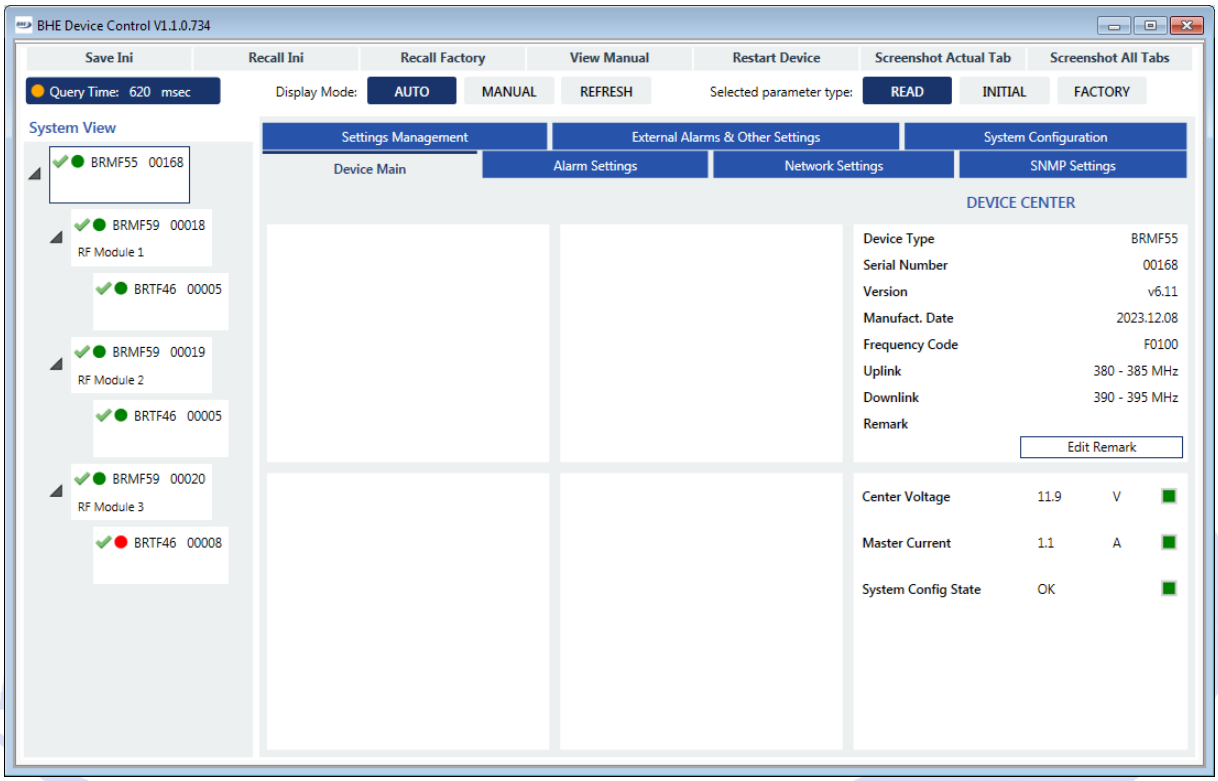
1.4.5 MASTER UNIT

If the master unit is selected in the System View the parameters of the master unit will be displayed on the right and middle parts of the screen.



Master unit manufacturing parameters

The upper part of the Device Center column shows the manufacturing parameters of the master unit.

- Device Type: Type of the device
- Serial number: Serial number of the device
- Version: Firmware version number of the device
- Manufact. Date: Manufacturing date of the device (YYYY.MM.DD)
- Frequency Code: The frequency code of the device. Determines the uplink and downlink frequency bands.
- Uplink: The uplink frequency band the device operates in.
- Downlink: The downlink frequency band the device operates in.
- Remark: Text field that can be edited by the operator (using the Edit Remark button)

Master unit monitored parameters

- Center Voltage: Measured value of the +12V supply.

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- Master Current: Current consumption of the master unit.
- System Config State: Shows if the current configuration of the system meets the configuration approved and stored in the master.

The green square near the data means the value is within normal range or the parameter is good while a red square indicates failure of the parameter.
In the Alarm Settings tab, the user can define the action the master will take for each alarm, which can be SNMP trap sending or dry contact relay activation. The front panel LED of the master device blinks continuously in case of any alarms in the master.

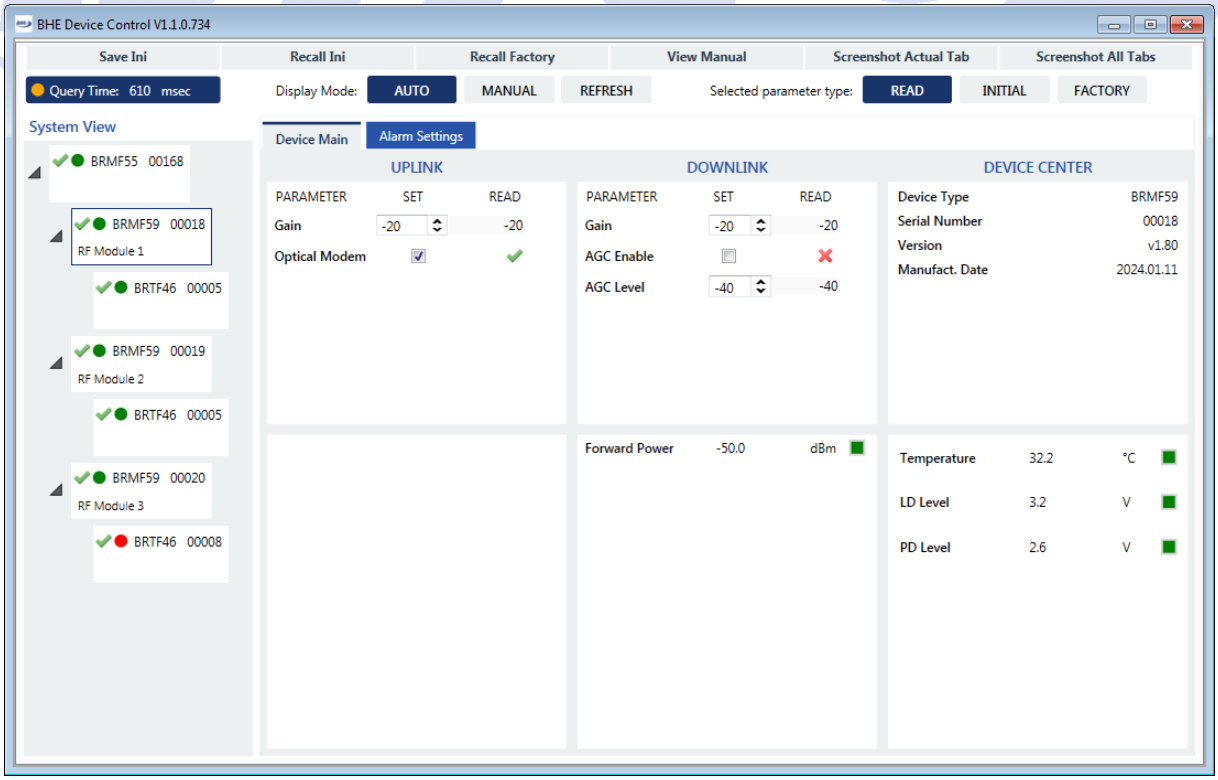
Master unit controlled parameters

The only controlled parameter in the master is the system configuration. For further details refer to chapters System View and System Configuration.

1.4.6 MASTER RF MODULE

If an RF module is selected in the tree structure the parameters of that module are displayed in the middle of the screen. Some of the parameters are related to the UPLINK/DOWNLINK sides while some parameters called “common” parameters are not dedicated to a specific side.

The front panel LED of the master device blinks continuously in case of any alarms in the RF modules.



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RF module controlled parameters

The controlled parameters can be changed by stepping the value up/down using the arrow buttons. The user can directly set the momentary values which take effect immediately and are displayed under column "SET". The momentary values can be stored as initial values using the "Save Ini" command on the Button bar. After power up the parameters start from the initial values. The initial values will be shown if the INITIAL parameter type is selected in the button bar. The user can recall the Initial values at any time using the "Recall Ini" command. Parameters that have momentary and initial values have factory values too. Factory values can be recalled with the "Recall Factory" button at the top of the window.

UPLINK controlled parameters

- Gain: The gain can be set in the range indicated in the datasheet at 1dB step. If the AGC function is On, the user cannot control the gain because it is automatically controlled by the RF module.

DOWNLINK controlled parameters

- Gain: The gain can be set in the range indicated in the datasheet at 1dB step. If the AGC function is On, the user cannot control the gain because it is automatically controlled by the RF module.
- AGC level: The AGC level can be set in the range indicated in the datasheet. The AGC function can be switched On/Off. If the AGC function is On the RF module controls the downlink gain to hold the downlink power getting to the optical modem within 1 dBm range of the AGC level. The uplink gain is set equal to the downlink gain. A downlink forward power error is indicated if the downlink power cannot be decreased to the desired level even with maximum attenuation.

Common controlled parameters

- Optical Modem: The power of the optical modem can be switched On/Off. The user can switch off an unused modem for power saving purposes. If a modem is switched off all connected slaves will be unavailable and will be displayed as lost in the System View window, provided they were stored in the configuration.

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RF module monitored parameters

DOWNLINK monitored parameters

- Forward Power: Forward power measured in dBm.

Common monitored parameters

- Temperature: RF module temperature in °C.
- LD Level: Laser diode monitor voltage of the optical modem.
- PD Level: Photo diode monitor voltage of the optical modem.

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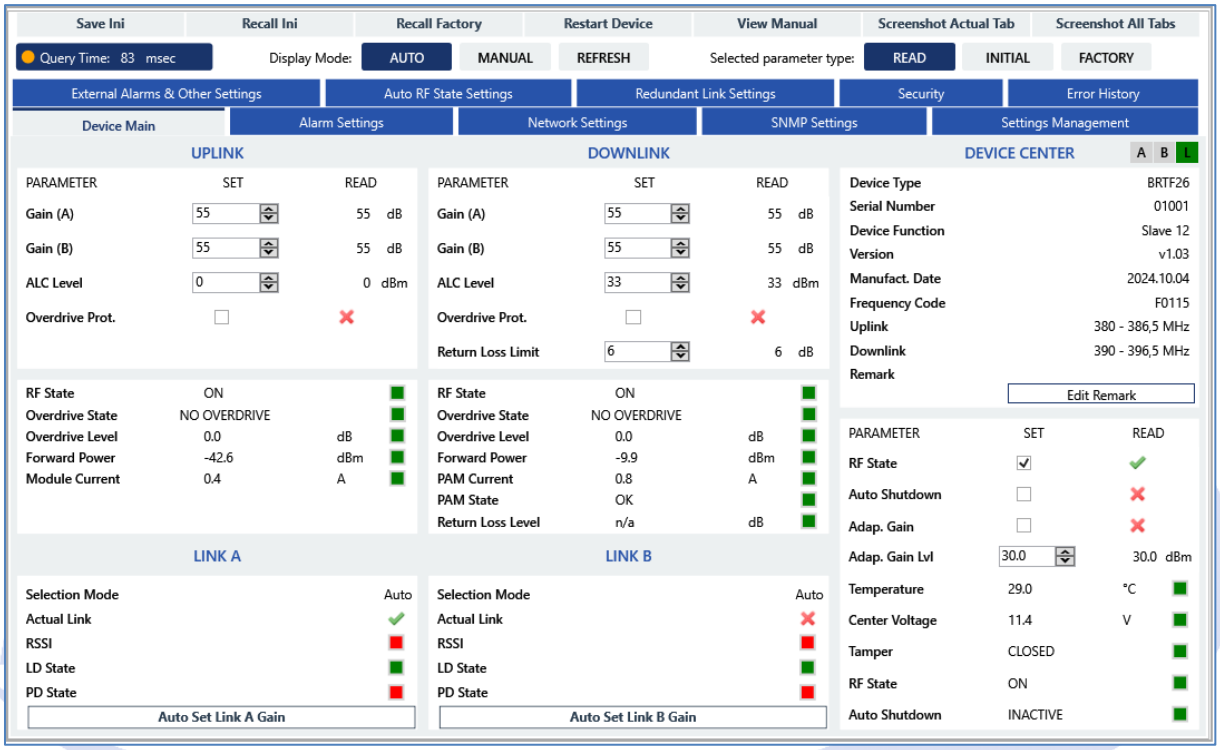
1.4.7 SLAVE DEVICE

If a Slave Device is selected in the tree structure the parameters related to the UPLINK/DOWNLINK modules are displayed in the middle of the screen while parameters that are independent of the two sides (common parameters) are displayed under column “DEVICE CENTER”.



Slave controlled parameters

The controlled parameters can be changed by stepping the value up/down using the arrow keys. The user can set the momentary values directly which take effect immediately and are displayed under column 'SET'. The momentary values can be stored as initial values using the "Save Ini" command in the Button bar. After power up the parameters start from the initial values. The initial values can be viewed in the second column by selecting the INITIAL display mode. The user can recall the Initial values at any time using the "Recall Ini" command in the Button bar. Parameters that have momentary and initial values also have factory default values. Factory values can be recalled with the "Recall Factory" command in the Button bar.

UPLINK controlled parameters

- Gain (A): The gain of the device can be set in the range indicated in the datasheet. The gain setting has a step of 1 dB. Separate values can be specified for the two optical links. The device will set the gain based on which link is momentarily active. This parameter sets the gain for link A.

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- Gain (B): The gain of the device can be set in the range indicated in the datasheet. The gain setting has a step of 1 dB. Separate values can be specified for the two optical links. The device will set the gain based on which link is momentarily active. This parameter sets the gain for link B.
- ALC Level: The ALC level can be set in the range indicated in the datasheet at 1 dBm step.
- Overdrive Prot.: The purpose of this function is to protect the repeater against working under overdrive condition for a long time. The function can be enabled/disabled. The operation of the function is detailed in chapter Special Device Functions.

DOWNLINK controlled parameters

- Gain (A): The gain of the device can be set in the range indicated in the datasheet. The gain setting has a step of 1 dB. Separate values can be specified for the two optical links. The device will set the gain based on which link is momentarily active. This parameter sets the gain for link A.
- Gain (B): The gain of the device can be set in the range indicated in the datasheet. The gain setting has a step of 1 dB. Separate values can be specified for the two optical links. The device will set the gain based on which link is momentarily active. This parameter sets the gain for link B.
- ALC level: The ALC level can be set in the range indicated in the datasheet. The step size is 1 dBm.
- Overdrive Prot.: The purpose of this function is to protect the repeater against working under overdrive condition for a long time. The function can be enabled/disabled. The operation of the function is detailed in chapter Special Device Functions.
- Return Loss Limit: A user-specified alarm threshold. An alarm is generated if the measured return loss is less than this value. Optional in slave units.

Controlled parameters of the optical links

- Auto Set Link A/B Gain: This button provides a quick and easy way to set up the gain of the device for the selected optical link. When this button is pressed, the device will switch to the corresponding optical link, and perform the adaptive gain functionality until the highest possible gain value is

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reached. The relevant Gain (A) or Gain (B) parameter is updated. Then, this value is saved as the initial (startup) value. As a last step, the device switches back to the optical link that was active before the button was pressed.

Common controlled parameters

- Edit Remark: Allows setting the remark string of the slave. This is a short user-defined text that identifies this device. It is included in SNMP trap messages.
- RF State: Enables or disables RF transmission.
- Adap. Gain: Enables or disables adaptive gain functionality. The operation of this function is detailed in chapter Special Device Functions.
- Adap. Gain Lvl: Sets the target level for the adaptive gain functionality. The device will try to reach this downlink forward power level when adaptive gain is enabled.

Slave monitored parameters

The green square near the data means the value is within acceptable range while a red square indicates failure of the parameter. The status of all monitored parameters that can generate an alarm are also listed in the Alarm Settings tab.
In the Alarm settings tab, the user can define the action the master will take for each alarm, which can be SNMP trap sending or dry contact relay activation. The front panel LED of both master and slave devices blink continuously in case of any alarms in the slave device.

UPLINK monitored parameters

- RF State: ON or OFF. The RF module is automatically switched off in the following cases: temperature alarm, overpower alarm, switch off by overdrive protection.
- Overdrive State: Indicates whether the unit is in overdrive. More details about overdrive indication can be found in chapter Special Device Functions.
- Overdrive Level: The momentary measured overdrive level in dBm.
- Forward Power: Forward power measured in dBm.
- Module Current: Current consumption of the Uplink RF module.

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DOWNLINK monitored parameters

- RF State: ON or OFF. The RF module is automatically switched off in the following cases:
  temperature alarm, overpower alarm, switch off by overdrive protection, switch off by mute function.
- Overdrive State: Indicates whether the unit is in overdrive. More details about overdrive indication can be found in chapter Special Device Functions.
- Overdrive Level: The momentary measured overdrive level in dBm.
- Forward Power: Forward power measured in dBm.
- PAM Current: Current consumption of the downlink power amplifier module.
- PAM State: Indicates whether the downlink power amplifier operates correctly.
- Return Loss Level: Shows the measured return loss. Note that this measurement is only performed when the downlink forward power is higher than 15 dBm. Optional in slave units.

Monitored parameters of the optical links

- Selection Mode: Shows the current link management mode (automatic or manual). This can be changed on the Redundant Link Settings tab.
- Actual Link: A green checkmark indicates the momentarily active optical link. The inactive link has a red X in this line.
- RSSI: Indicates whether the received signal strength ratio is above the user defined limit for the link. The limit can be changed on the Redundant Link Settings tab.
- LD State: Indicates whether the laser diode of the optical modem operates correctly. A composite alarm is show here, which takes into account the user-defined alarm limit on the Redundant Link Settings tab, as well as a digital alarm signal from the optical modem.
- PD State: Indicates whether the photo diode of the optical modem operates correctly. A composite alarm is show here, which takes into account the user-defined alarm limit on the Redundant Link Settings tab, as well as a digital alarm signal from the optical modem.

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Common monitored parameters

The common monitored parameters are shown in the lower part of column "DEVICE CENTER".

- Temperature: Temperature of the slave device.
- Center Voltage: Measured value of the +12V supply voltage.
- RF State: Indicates whether RF power is currently enabled.
- Fan: Indicates whether the fan is currently operating. An alarm is shown if the fan current consumption is too high.
- Tamper: Indicates an alarm when the housing of the device is open.
- Auto RF State: Indicates whether the Auto RF State functionality is active.

1.4.8 SPECIAL DEVICE FUNCTIONS

Overdrive indication and overdrive protection

Overdrive can arise in the slave repeater if the gain is too high (output level would exceed the ALC level) or a mobile phone is too close to the uplink antenna.

Overdrive is indicated by parameters "Overdrive Level" and "Overdrive State".

Overdrive Level is shown in dBm units and is calculated from the ALC regulating voltage. This parameter shows approximately how much the input power needs to be decreased for the overdrive to cease. If the Overdrive Level is in normal range (< 6 dBm) no overdrive is indicated. The square near the Overdrive Level value is green and Overdrive State will show "No Overdrive".

If the Overdrive Level is too high (over 6 dB for slave units), a momentary overdrive status is indicated. The square near the Overdrive Level changes to red and Overdrive State will show "Warning".

If the overdrive condition does not cease for 30 minutes, the Overdrive State parameter will show "Overdrive over 30 min". This creates an alarm in the device which can cause a trap message to be sent or dry contact relay activation depending on the trap and dry contact masks set by the user (see chapter Alarm Settings for information on how to set the alarm masks).

If the continuous overdrive exceeds 30 minutes and the overdrive protection is enabled the amplifiers of the uplink and downlink modules will be switched off for 1 hour. The "Module State" among the monitored parameters will show “OFF”.

After 1 hour has elapsed since switching off RF power, the uplink and downlink amplifiers are switched on for 10 seconds to check if the overdrive condition is still present or not. The Overdrive State parameter will show "Overdrive (trying)".

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If the overdrive still exists the amplifiers will be switched off again for 1 hour. If there is no overdrive at the end of the 10 second check period, RF power remains switched on and the repeater operates normally.

Adaptive gain functionality

The adaptive gain function has two modes of operation: Fast mode and Slow mode.

Fast mode:

Fast mode starts in the following cases:

- After power on if the initial state of the function is on.
- After the user has switched on the function.
- The adaptive gain target level was changed.
- The user presses the Auto Set Link A/B Gain button. In this case, the device does not switch into slow mode once the fast mode is over.

During fast mode operation the repeater continuously monitors if there is overdrive or not. The monitoring is performed by sampling the ALC level of the downlink module every second. If the ALC level is within the appropriate range, that is, there is no significant overdrive, the gain of the repeater is increased by 1 dB in both the uplink and the downlink modules until the downlink forward power reaches the preset adaptive gain target level. In case of overdrive, or if the downlink forward power is over the target level, the gain is decreased. The increase/decrease of the gain is performed by modifying the gain value which can be seen in the control software.

Fast mode ends after the gain has been decreased for the first time, or the target downlink forward power level has been reached, or the gain has reached its maximum or minimum value.

Slow mode:

The slow mode operation of adaptive gain starts after Fast mode has ended. During slow mode the overdrive is monitored just like in fast mode. The difference is in the periods of increasing/decreasing the gain. In slow mode, the gain is increased by 1 dB only if there is no overdrive for 1 minute. The gain is decreased by 1 dB if overdrive occurred in the last second or if the downlink forward power is above the target level. So, the maximal gain increase speed is 1dB/minute and the maximal gain decrease speed is 1 dB/second in slow mode. In fast mode, both speeds are 1dB/second.

When adaptive gain is active, the gain and ALC level cannot be set by the user and the initial /factory values of these parameters cannot be recalled. The ALC level is automatically set to the factory preset value.

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Auto RF State functionality (optional)

The device is capable of monitoring various alarm conditions and can turn RF power on and off, based on user-defined criteria. For instructions on configuring this function in the user interface, see chapter Auto RF State.

The device is capable of automatically turning transmission on and off based on pre-defined criteria. This functionality can be configured with the following parameters:

- Decision mask
- Logical condition
- Affected Modules
- Default RF Mode
- Timer Reload Value and Remaining Time

The first two parameters determine the criteria when the function should activate. When it activates, the function will enable or disable RF transmission based on the Default RF Mode setting. The decision mask can be used to select which alarm conditions need to be active to induce the activation of the function. The logical condition determines if all selected alarm conditions must be present at the same time, or if the function should activate when any of the selected alarms is present.

The Affected Modules setting determines whether only the uplink, only the downlink, or both uplink and downlink modules should be managed (turned on or off) when the function activates.

The Default RF Mode setting determines whether RF transmission of the Affected Modules should be on or off by default. In most cases, the default state would be on, meaning that transmission is active most of the time, but under certain conditions (determined by the Decision Mask and Logical Condition) it would be turned off. Using the Auto RF State functionality in this way can be useful when the goal is to prevent some unwanted effect. For example, if the unit is supplied by mains power and a UPS, the unit could be configured to automatically disable transmission after a certain time when the power goes out, to avoid discharging the UPS battery.

The Default RF Mode can also be set to off state. This can be useful when the repeater must only be activated under specific conditions. For example, if the unit provides coverage for a enclosed space or room, where no-one is present most of the time, the External Alarm input of the device could be connected to the door switch of the room, and the unit could be set up to only activate when someone is inside. This avoids unnecessary operation, which lowers electricity costs, and increases the lifetime of the unit.

When the conditions specified by the Decision Mask and Logical Condition are met, the function activates and turns the Affected Modules on or off (based on the Default RF Mode setting). A timer is also available which determines how long the function will stay activate after the conditions have ceased.

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The user can specify the reload value of the timer. When the function activates, the timer starts counting back from this value. The momentary value can be seen in the Remaining Time parameter. The timer is reset to the Reload Value every time the conditions for activating the function are met.

When the Reload Value is set to zero, the function will only be active as long as the user-defined conditions are present. As soon as the conditions cease, it will be deactivated.

It is possible to immediately activate the function by manually changing the Remaining Time parameter. In this case, the function is activated, and the timer start counting down from the specified value. The function is deactivated when the Remaining Time reaches zero.

Transmission will stay disabled as long as the conditions are met. Once the conditions cease (i.e. at least one of the selected alarms becomes inactive), RF power is enabled again.

Uplink mute functionality (optional)

The device is capable of monitoring the uplink RF input power and switching off transmission if it is below a user-specified level.

The mute function has one configurable input parameter: the threshold level (Mute Level in the control software).

When the Mute functionality is activated, the device continuously monitors the level of the uplink side input signal. If the RF input power does not rise above the mute threshold level for 3 seconds, the device will switch off transmission in the uplink side. If a useful signal with proper signal strength (higher than the threshold level) is detected at any time, transmission is switched on immediately. The typical delay for switching transmission on is about 10 µs.

Note that the slave units might not support Mute Levels lower than -75 dBm, even though it is possible to set the level lower than this.

Automatic Gain Setting

The device is capable of automatically setting the gain for each link so that the downlink forward power reaches the level specified by the Adap. Gain Lvl. parameter. When the Auto Set Gain A or Auto Set Gain B button is pressed, the device starts the adaptive gain procedure in fast mode. The difference compared to normal adaptive gain operation is that when the device reaches the target downlink forward power level, instead of switching to slow mode, it will stop the adaptive gain procedure and stores the momentary gain setting for the selected link as the initial value. This functionality is intended to make the initial setup of the repeater easier.

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Note that when the Auto Set Gain A / B button is pressed, the device will automatically switch over to the selected link, if needed. When the procedure is done, it will switch back to the original link.

It is possible to stop the automatic gain setting at any time during the procedure. To interrupt the process, simply switch off adaptive gain using the checkbox in the DOWNLINK column of the GUI. In this case, the initial switch state will be restored, but the momentary gain value will not be saved.

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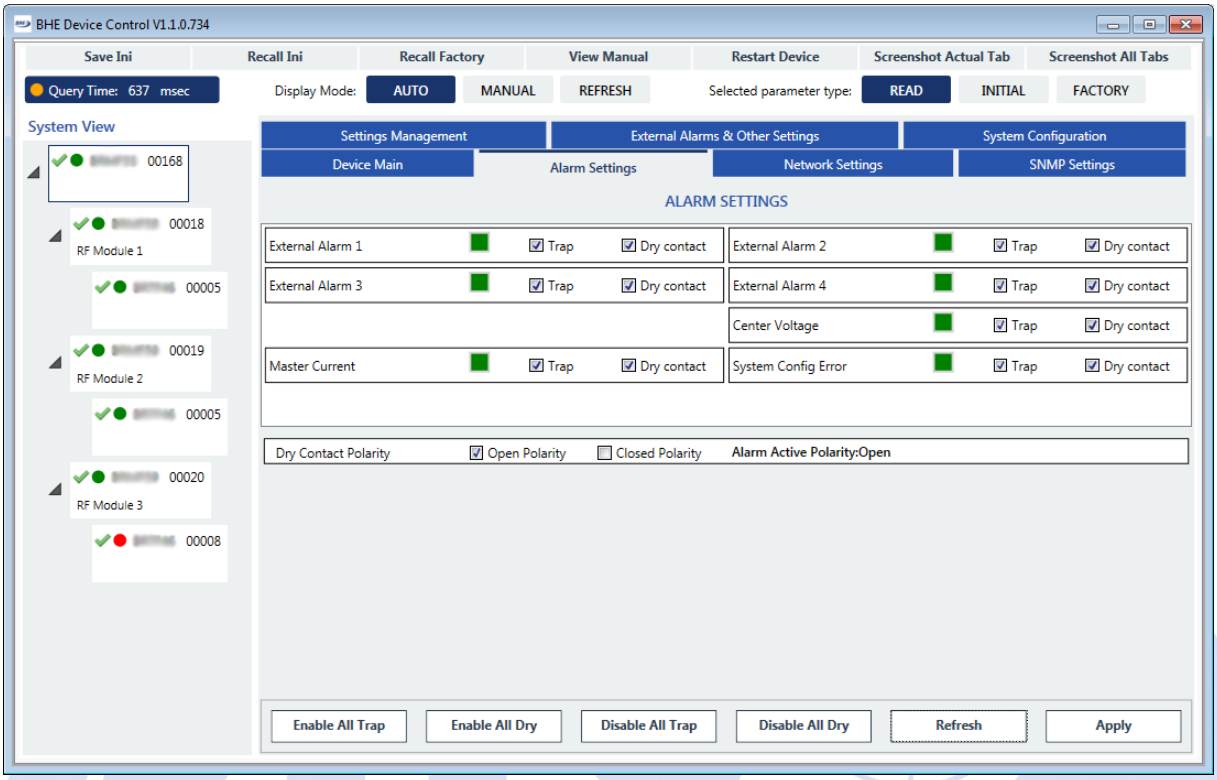
1.4.9 ALARM SETTINGS



Master Center Module Alarm Settings

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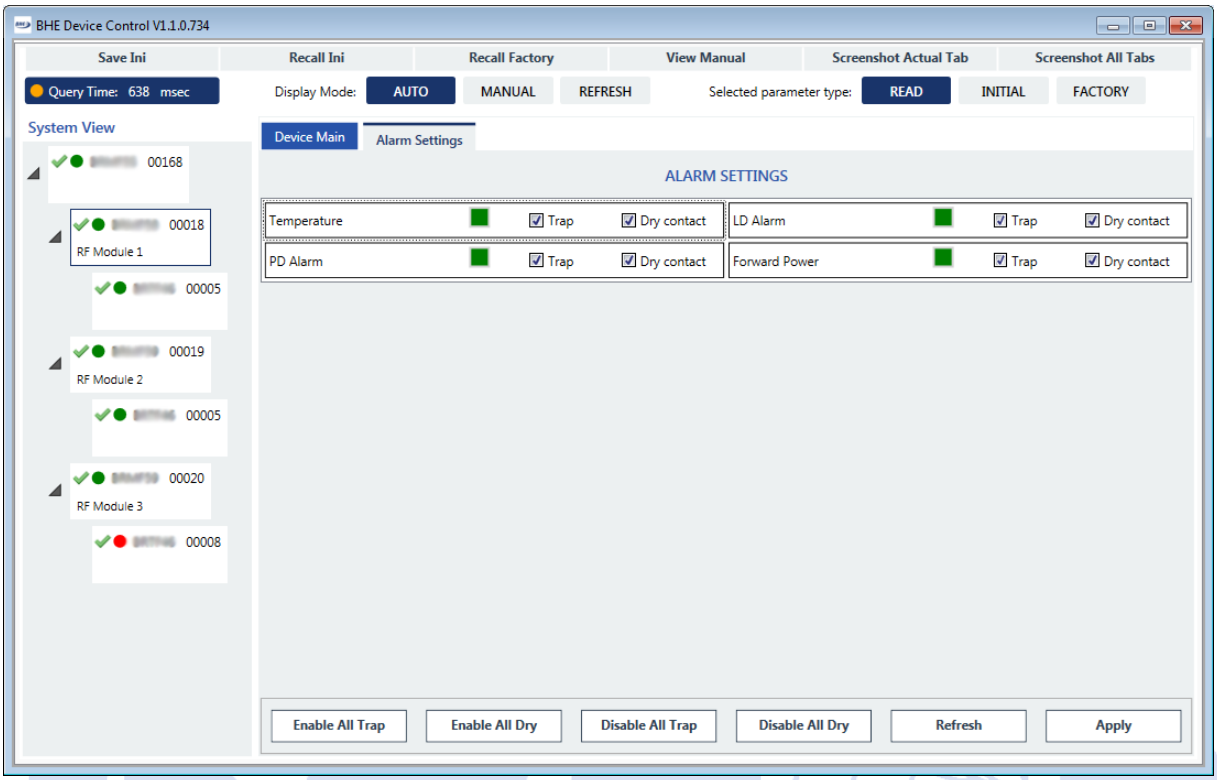

Master RF Module Alarm Settings

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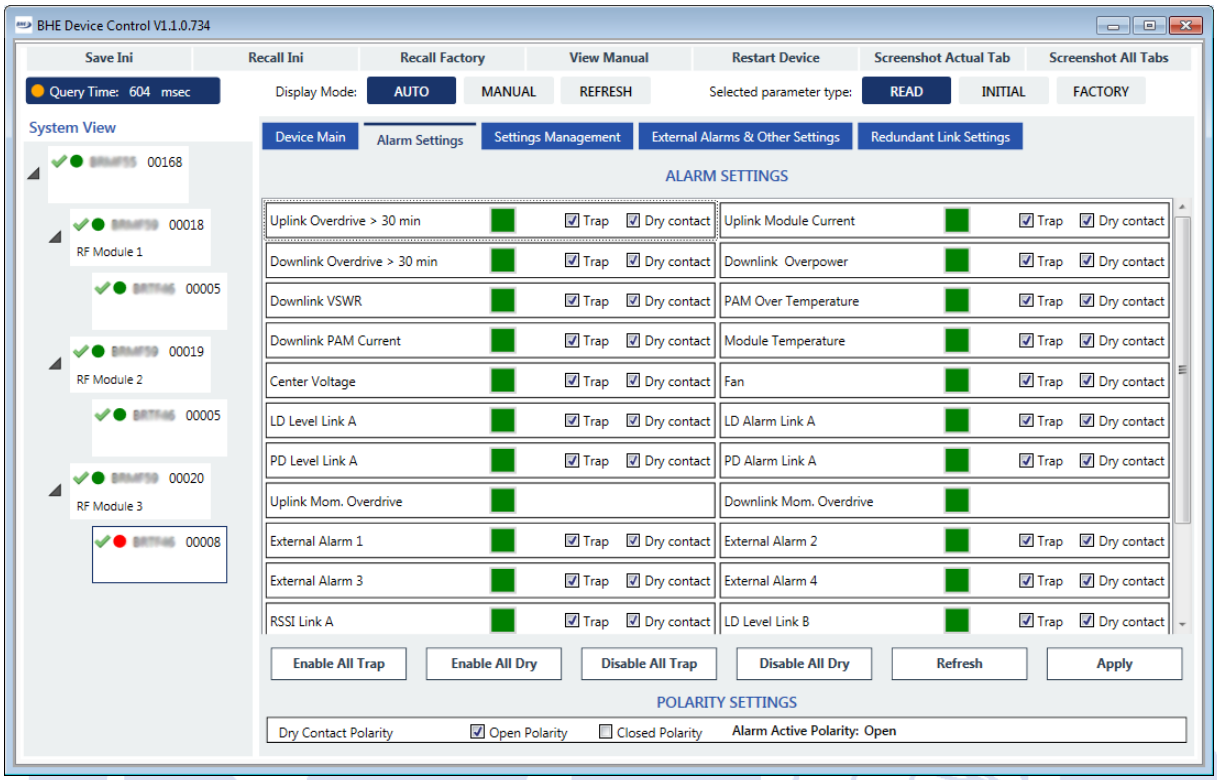

Slave Unit Alarm Settings

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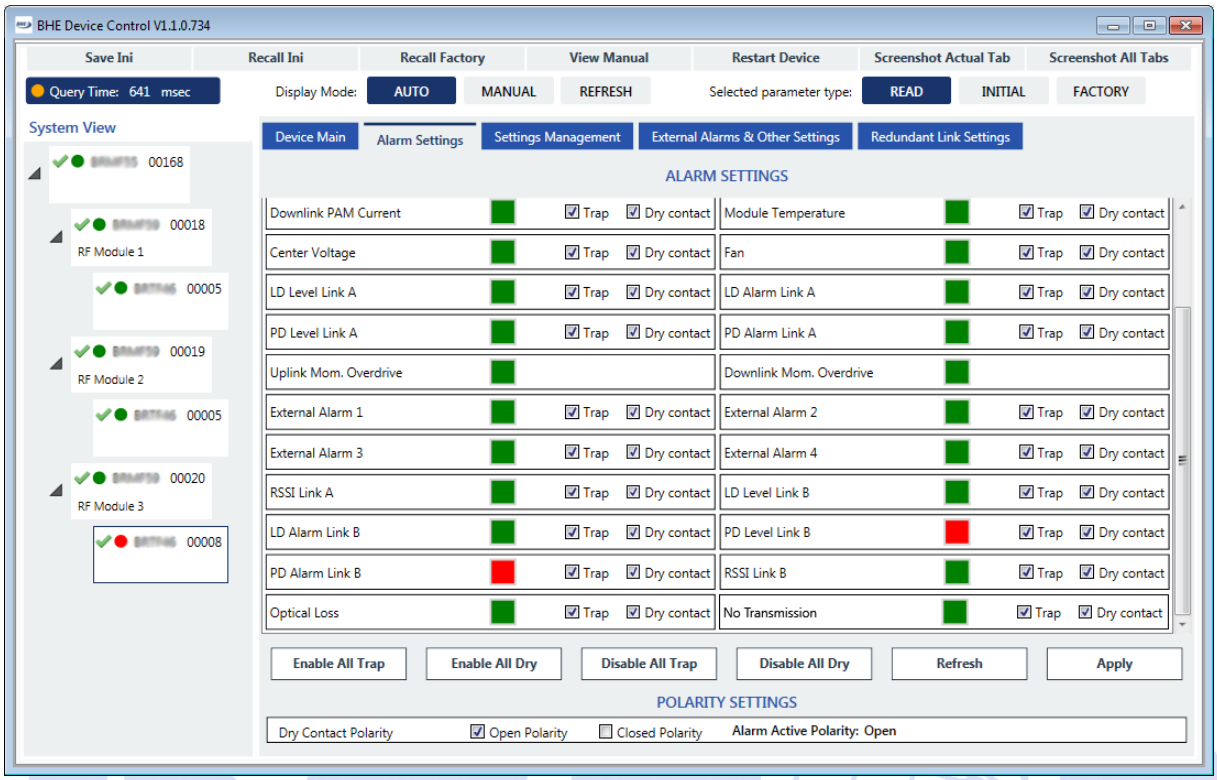

Slave Unit Alarm Settings

Failure of a monitored parameter results in an alarm in the system. There are as many alarm sources in the system as many monitored parameters that can have failure. In the Alarm Settings window, the user can enable/disable each alarm source both for SNMP trap sending and for dry contact relay activation. Disabled alarm sources are considered to be correct when device status is determined for trap sending and dry contact activation. Disabling alarm sources does not affect the front panel status LED alarm indication of the repeaters.

All the alarm sources that are present in the selected module (Master Center, Master RF module, slave device) are displayed after opening the Alarm Settings tab.

A green or red colored square indicates the momentary status of each alarm. They are colored red if the parameter is outside acceptable limits, or colored green if the parameter is within limits. By checking the checkbox labelled "Trap" near the parameter the user can enable the alarm source for SNMP trap sending. By checking the checkbox labelled "Dry contact" the alarm source can be enabled for dry contact management.

Note that SNMP trap sending is globally enabled/disabled in the SNMP Settings tab. This tab also controls other parameters e.g. timing intervals of SNMP trap sending.

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Note that the master unit will send trap messages for all connected devices. It is not necessary to directly connect individual slaves to the monitoring system to get their status information. However, slaves can also send their own trap messages, if needed. This can be enabled in the SNMP Settings tab when connected directly to a slave unit.

Slave alarms affect the dry contact relays in both the master and slave units (if installed). Master center and master RF module alarms affect only the dry contact relay built in the master device.

After making the desired settings, they can be applied and stored in the selected device by clicking the "Apply" button. To update the trap and dry contact relay masks, click the "Refresh" button. The status of the alarms is updated automatically. Note that Alarm settings are not affected by the Save Ini, Recall Ini and Recall Factory Settings commands, as they are saved immediately.

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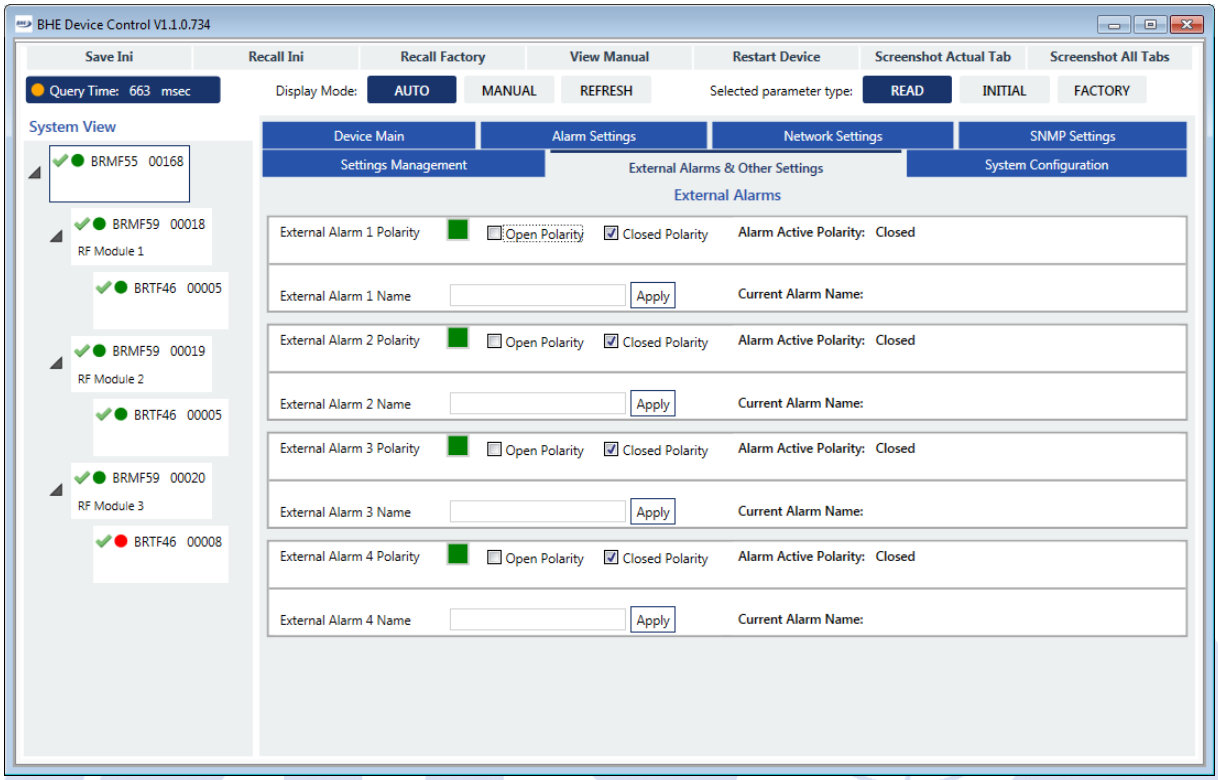
1.4.10 EXTERNAL ALARMS & OTHER SETTINGS



The polarities and names of the external alarm inputs can be configured on the External Alarms & Other Settings tab of the control software.

Each external alarm has a polarity and a name associated with it. The polarity determines when the alarm input is considered to be in "alarm" state. If the polarity is set to "Open", then the device will consider that external alarm input to be in "alarm" state when there is no connection between the input and the ground. If the polarity is set to "Closed", then the device will consider that external alarm input to be in "alarm" state when there is a connection between the input and the ground.

The name of the external alarm is a short string (20 characters) that identifies the given alarm (e.g. "Battery Low"). Using ASCII characters is recommended. The alarm names are included in every trap message.

New alarm names can be sent to the device by hitting enter, or by clicking the Apply button next to each text field.

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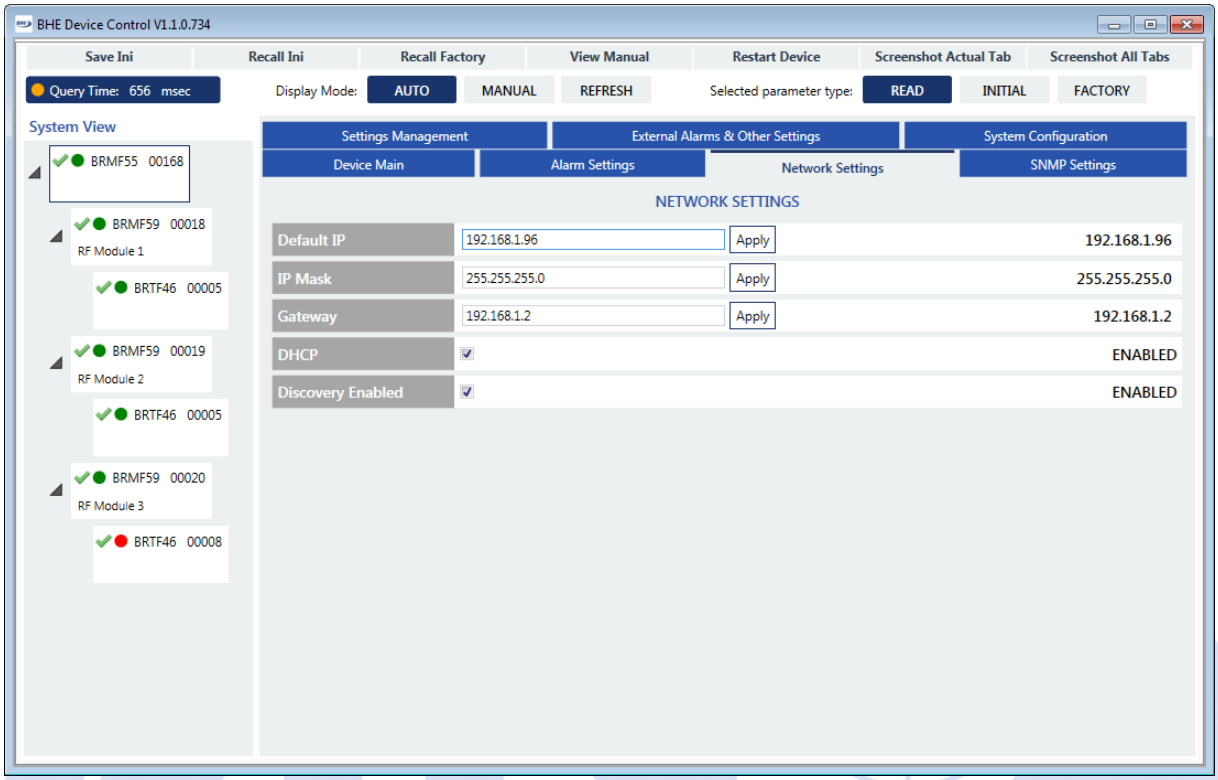
1.4.11 NETWORK SETTINGS



In the Network Settings window, the user can set the network parameters of the device they are directly connected to. The default IP address, subnet mask and gateway address can be set. DHCP can be enabled or disabled. For a detailed description of how the IP address of the device is determined, see chapter Ethernet Interface.

New values can be sent to the device by pressing enter in any of the edit fields in this tab, or by clicking the Apply button. The new values are saved in the device immediately, however, the repeater needs to be restarted for the new settings to take effect.

Answering BHE Product Finder messages can be disabled by unchecking the Discovery Enabled checkbox. In this case, the device will not appear in the Product Finder.

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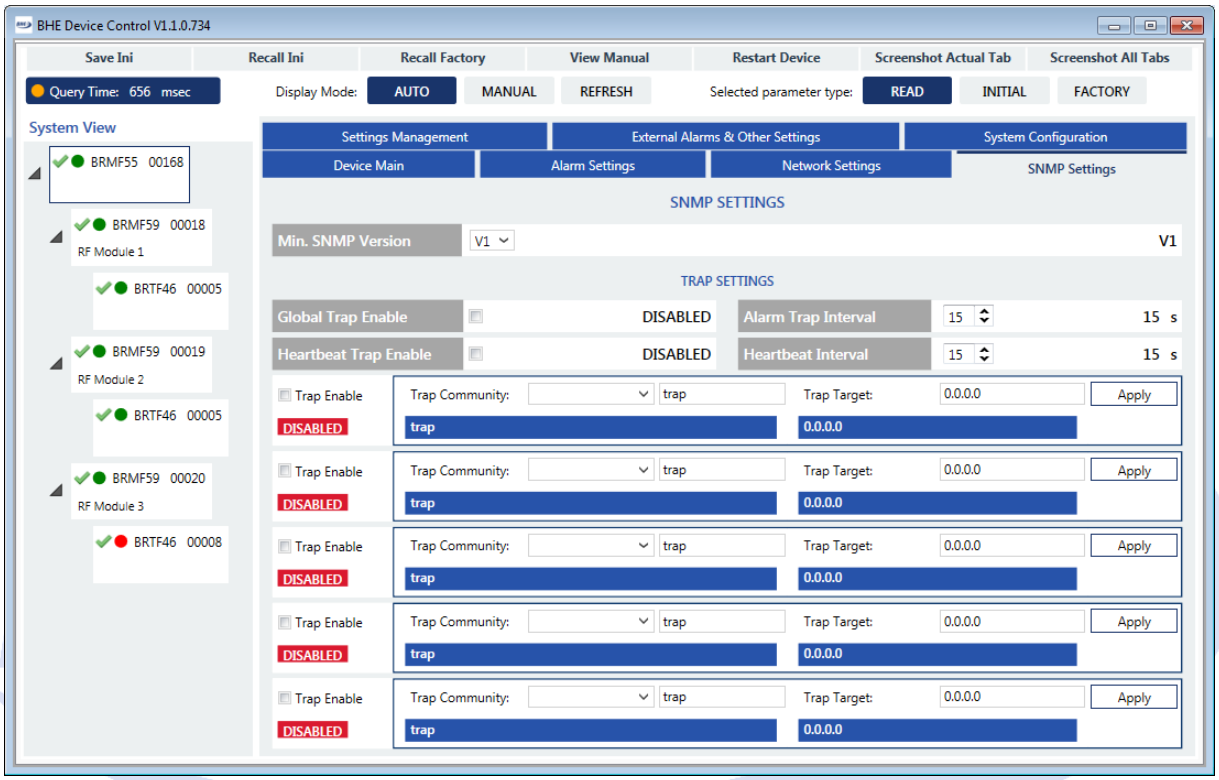
1.4.12 SNMP SETTINGS

The master unit can send SNMP v2c/v3 trap messages about alarms that occur in the system (including RF modules in the master frame and slave units). The slave unit can send trap messages about alarms that occur in the slave. The trap sending functionality can be configured in the SNMP Settings tab.



The following SNMP and trap sending-related parameters can be set:

- Min. SNMP Version: Determines the minimum SNMP protocol version that the device requires from incoming requests. Requests that have a lower version number than this are ignored. Only administrators can change this setting. Changes take effect after restart.
- Global Trap Enable: Enables or disables trap sending globally.
- Heartbeat Trap Enable: Enables or disables trap sending when the device operates without alarms.
- Alarm Trap Interval: Time interval in seconds between two consecutive traps that contain the same alarm information. If the alarms of the device change, a trap message is sent immediately.

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- Heartbeat Interval: Time interval in seconds between two consecutive heartbeat traps.
- Trap Enable: Up to five different trap destinations can be set (these are the IP addresses of the managers that need to monitor the repeater). Each trap destination can be enabled/disabled individually.
- Trap Community: The trap community in case of SNMP v2c traps, or a username in case of SNMP v3 traps. Since SNMP v3 uses authentication and optional encryption and these parameters can be set separately for each user, the username set here must be of an active user that is already present in the system.
- Trap Target: The destination IP address trap messages will be sent to. Generally, this is the IP address of an SNMP manager.

Trap generation of each alarm source can be enabled/disabled in the Alarm Settings tab of the unit.

Note that traps can be sent by both the master and slave devices. If the master unit is configured for trap sending, it will send separate trap messages for each connected device (including RF modules). Alarms that generate traps can arise in any part of the system (master center module, master RF modules, slave devices). Trap generation of each alarm source can be enabled/disabled in the Alarm Settings window of the related unit.
If the slave unit is configured for trap sending, it will only send its own trap messages, since it has no information about other parts of the system.

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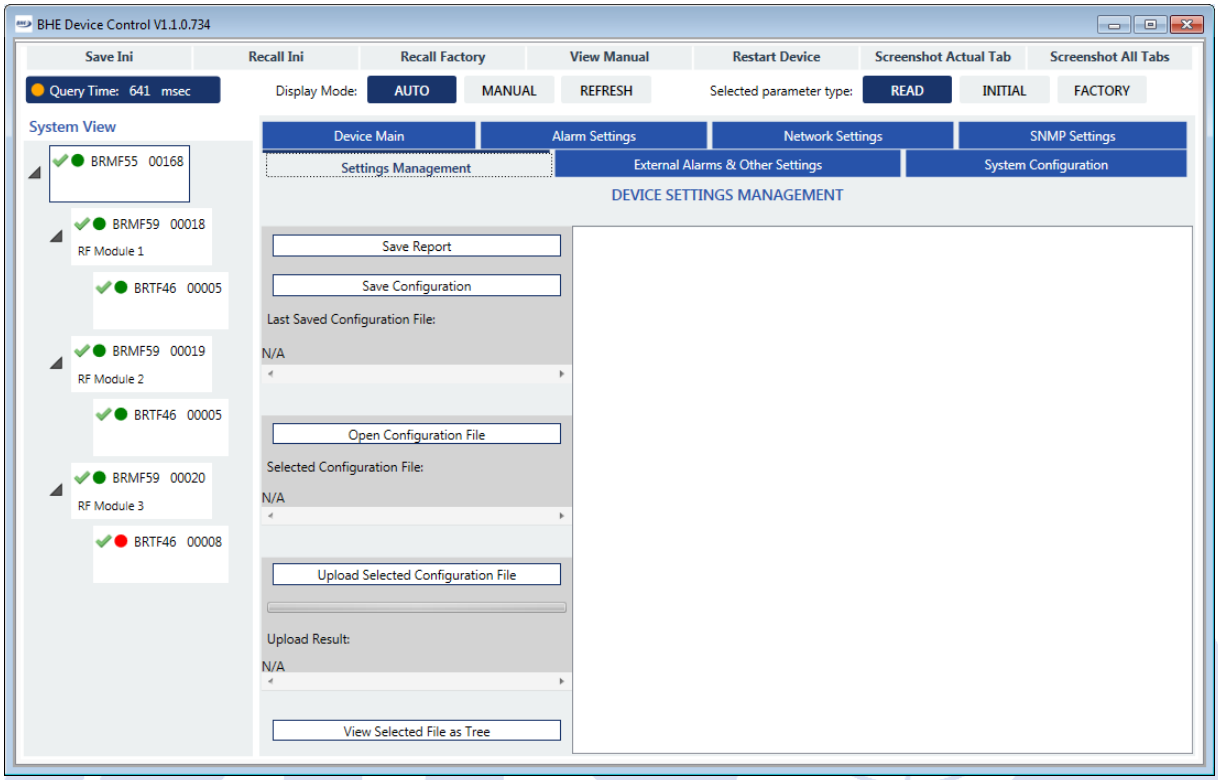
1.4.13 SETTINGS MANAGEMENT



The Settings Management tab in the control software allows saving and loading the settings of a single device. Settings files are saved in human-readable XML format.

Settings saving and loading is available for the master unit, and for each slave unit.

When the master unit is selected in the System View on the left side of the control software, the parameters of the master unit (including all the RF modules) will be saved. Note that RF module parameters are position dependent. This means that when a configuration is loaded into the master unit, the saved parameters of the first RF module will be loaded back into the first RF module, even if the first RF module is not the same device as when the configuration was saved (e.g. because the first RF module has been swapped with a spare part).

Slave configuration is *not* position-dependent. This means that a saved slave configuration can be loaded into any slave unit in the system, even if the saved configuration is not of a slave unit in that position. E.g. the configuration of Slave 12 (RF module 1, slave 2) can be safely loaded into Slave 34 (RF module 3, slave 4) after selecting Slave 34 in the System View.

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The following functionality is provided:

- Save Report: Save a report file containing all controlled and monitored parameters of the device. This file is ideal for e.g. documenting current settings at time of installation.
- Save Configuration: Save a configuration file containing all controlled parameters of the device.
- Open Configuration File: Open a report or configuration file. The settings contained in the file can be viewed in the control program and uploaded to the device.
- Upload Selected Configuration File: Uploads the selected configuration file to the current device. All controlled parameters in the device will be updated, including initial values.
- View Selected File as Tree: Displays the parameters contained in the selected configuration file in the panel on the right.

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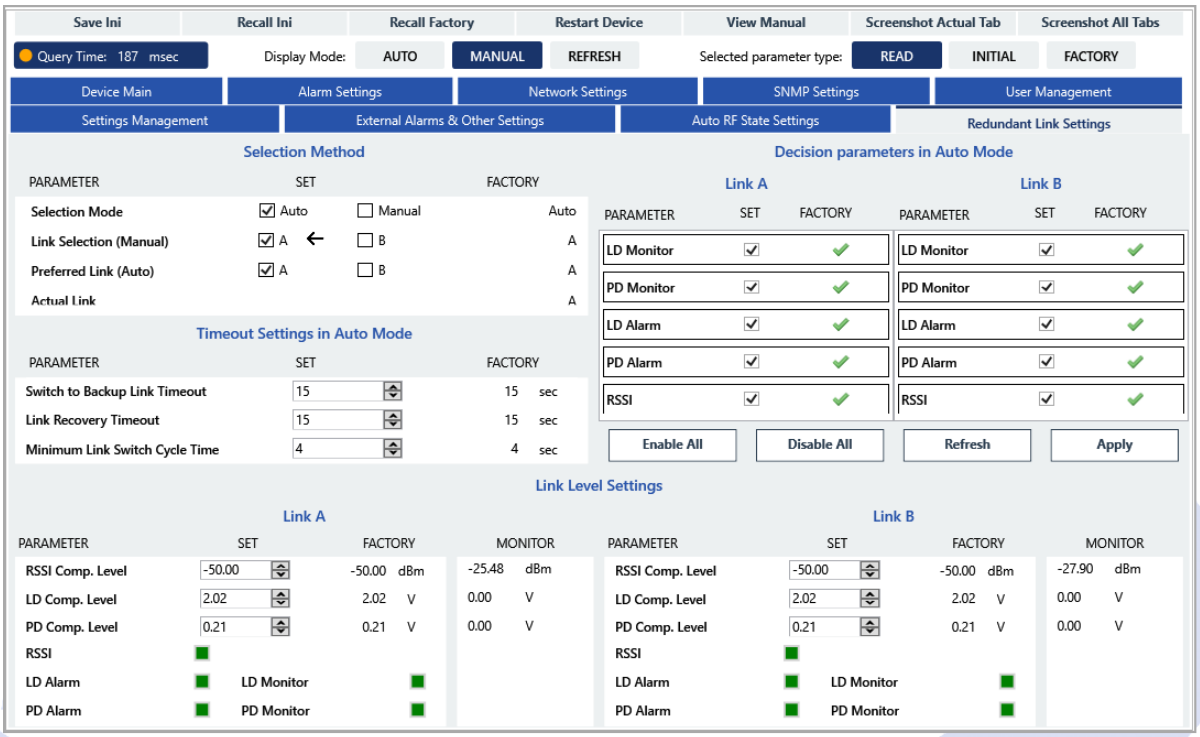
1.4.1 REDUNDANT LINK SETTINGS

In the Redundant Link Settings tab the parameters of the redundant operation of the slave device can be controlled and monitored.



Redundant operation means the following two cases:

1. The slave device is connected to two master devices through optical cables.
2. The slave device is connected to one master device but through two different optical cables.

The following description covers case 1 but case 2 is very similar to it and has the same parameters.

The RF signal between the master and slave can be transmitted only towards one master at a time. This master is selected by the RF Switch in the slave. The two positions of the RF Switch are Link A and Link B.

The control and monitoring of the slave device by the master is independent from the RF switch position; it is performed in parallel, by both masters at the same time. The RF Switch can be operated manually by the user or automatically by the software algorithm of the slave device. The automatic selection is based on the evaluation of the selected decision parameters of the two links. The program determines the number of failed parameters on both links. The algorithm

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will select the link that has the smallest number of failed parameters. If the number of failed parameters of the two links is equal the algorithm will select the "Preferred link" set by the user.

Selection Method options:

These settings determine how the RF switch position should be managed.

- Selection Mode: Manual: The RF Switch position is determined by the user. Auto: The RF Switch position is determined by the slave device.
- Link Selection: The selection of the user in Manual Mode (Link A or Link B). The black arrow between the two possible selections shows which link would be selected by the slave device in Auto mode.
- Preferred Link: The Preferred Link will be selected in Auto Mode if the algorithm finds both links of equal quality (i.e. both have the same number of failed parameters).
- Actual Link: Indicates which link is currently selected.

Decision Parameters in Auto Mode:

In this part of the window the user can select the parameters that take part in the evaluation of the two links. Clicking the box selects/deselects the parameter. A deselected parameter will count as good when determining link quality.

RSSI: The strength of the RF signal received from the master measured in dBm.

PD Monitor: Voltage detected by the photodiode of the optical modem.

PD Alarm: Digital photodiode alarm signal generated by the optical modem.

LD Monitor: Voltage detected by the laser diode of the optical modem.

LD Alarm: Digital laser diode alarm signal generated by the optical modem.

Link Level Settings:

In this part of the window the user can set the comparison level of the evaluated parameters. If a parameter is under the comparison value it is considered to be correct otherwise it will be considered failed.

Note that PD and LD Alarms come directly from the optical modem, so comparison levels cannot be set for them.

The momentary level of the parameters is also displayed in the window together with the result of the evaluation: a green square is shown for correct parameters and a red one for failed parameters.

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Timeout Settings in Auto Mode:

These settings determine when a switch between the optical links can occur. The following parameters are available:

- Switch to Backup Link Timeout: Specifies how long the non-preferred optical link must have better parameters than the preferred link for a switch to the non-preferred to occur.
- Link Recovery Timeout: Specifies how long the preferred optical link must have better parameters than the non-preferred link for a switch back to the preferred to occur.
- Minimum Link Switch Cycle Time: Specifies the minimum time between two optical link switches.

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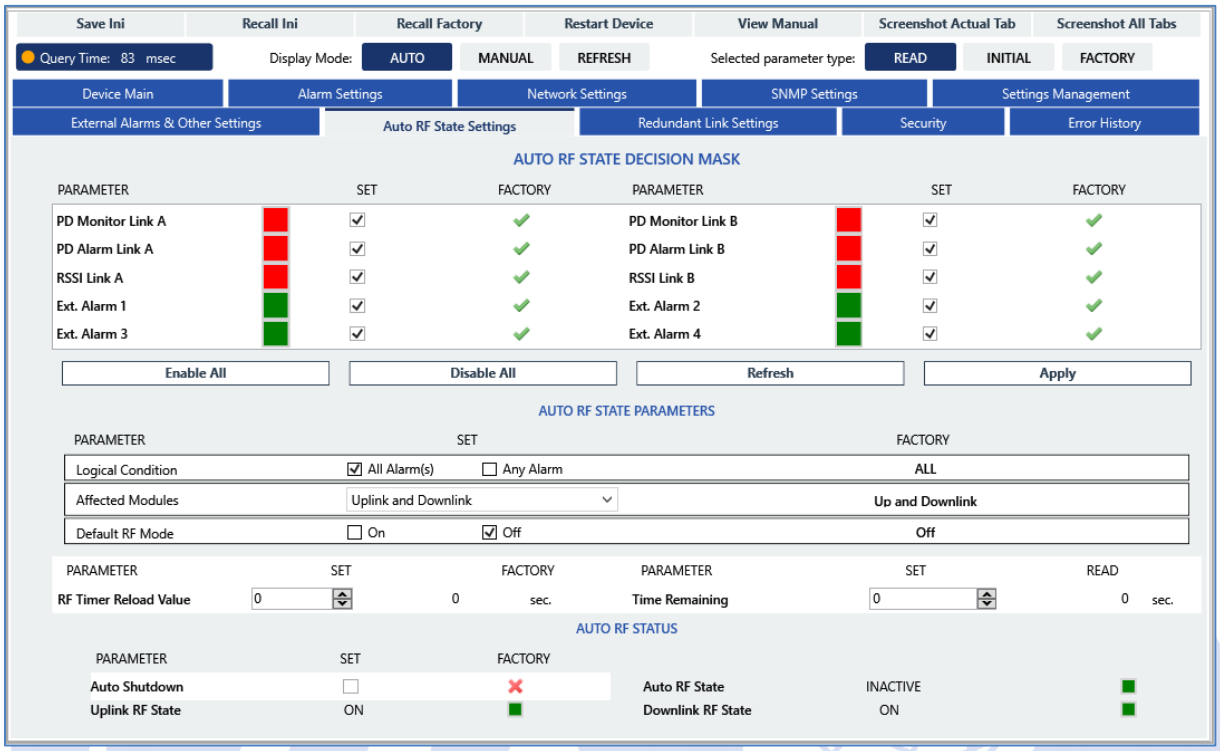
1.4.2 AUTO RF STATE



The Auto RF State tab of the control software allows configuring parameters related to the function of the same name. For a detailed description of its operation, see the relevant part in section Auto Shutdown functionality (optional).

The functionality can be enabled or disabled on the main screen, under the Slave Center column, or on the Auto RF State tab.

The following options are available:

- Decision Mask: Determines the alarm conditions that can induce the activation of the function.
- Logical Condition: Determines if all selected alarm conditions must be active at the same time to induce activation, or if any alarm will do so.
- Affected Modules: Determines which modules should be managed by the function (uplink, downlink, or both).
- Default RF Mode: Determines whether RF should be on or off by default. When the function activates, transmission will be temporarily set to the inverse

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of this setting (that is, when the Default RF Mode is on, transmission will be disabled when the function activates and vice versa).

- RF Timer Reload Value: Specifies the value that will be loaded into the timer when the function activates. It will start counting down from this. The function will stay active while the timer counts down. If set to zero, the function will deactivate immediately when the activation conditions cease.

- Time Remaining: Shows the momentary value of the timer. Can also be used to manually activate the function by setting a non-zero value.

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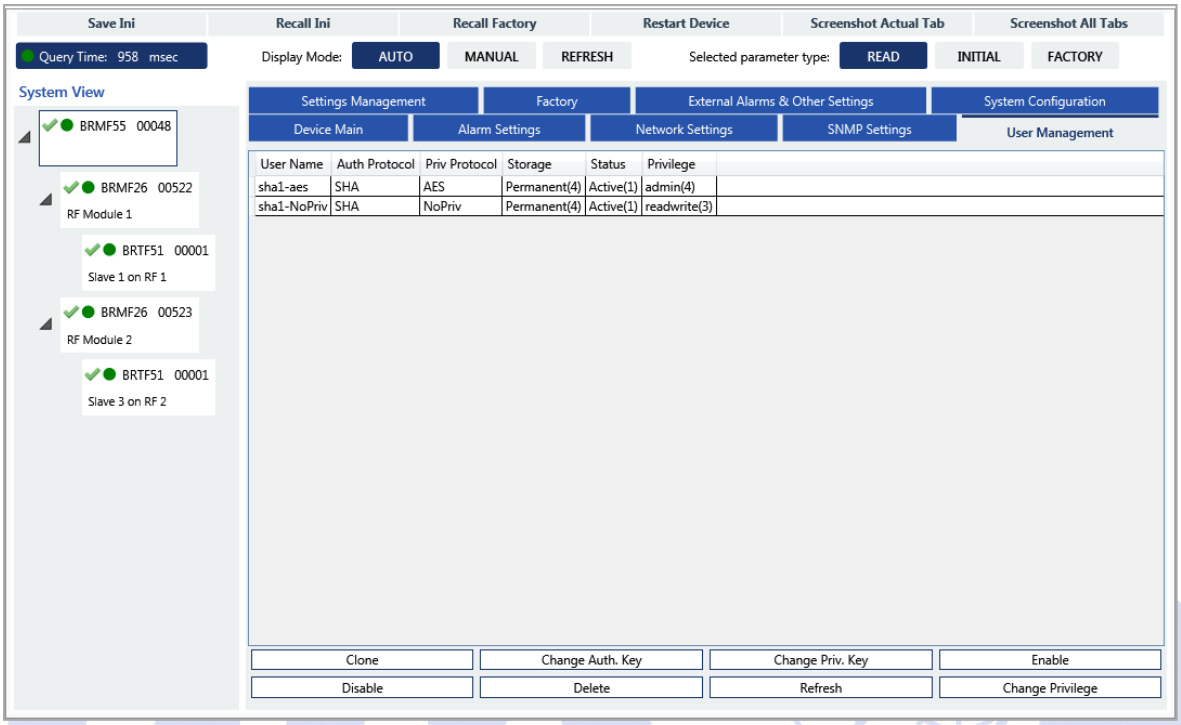
1.4.3 USER MANAGEMENT



The User Management tab provides an interface for managing SNMP v3 users in the device. For an in-depth description of user management, see chapter User Management.

The users currently present in the device are listed in the table in the middle of the tab. This table displays the username, authentication protocol, privacy protocol, storage type, status and privilege level parameters of the users.

The following operations can be performed through the control software:

- Clone: Create a clone (copy) of the selected user. This is the first step of setting up a new user in the device. The authentication protocol, authentication password, privacy protocol and privacy password parameters are copied from the selected user, while the storage type, status and privilege parameters are set automatically by the device.
- Change Auth. Key: Change the authentication password of the selected user.
- Change Priv. Key: Change the privacy (encryption) password of the selected user.

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- Enable: Change the selected user's status from "not in service" to "active". The user can be used to access the device afterwards. Access rights are determined by the user's privilege level.
- Disable: Change the selected user's status from "active" to "not in service". The user will become unable to access the device afterwards.
- Delete: Delete the selected user. Note that users with permanent storage type cannot be deleted. The last user with administrator privilege level cannot be deleted.
- Refresh: Query the user configuration from the device and update the table.
- Change Privilege: Change the privilege level of the selected user.

All changes on this tab are applied and saved immediately. New users can be used right away after activation.