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BHE Analog Off-air Repeaters

(Band Selective TETRA)

SOFTWARE USER MANUAL

Technical Documentation.

Revision 02

Developer and manufacturer:

BHE Bonn Hungary Electronics Ltd.

H-1044 Budapest, Ipari Park Str. 10.

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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1 DOCUMENT CHANGE RECORD

ISSUE	DATE	MODIFIED BY	REASON FOR CHANGE AND AFFECTED SECTIONS
Rev 01	2024-08-13	Gergely DOBOS	Initial version.
Rev 02	2025-03-10	Gergely DOBOS	Removed PO box from document header. Added chapters on user management.

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2 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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3 SOFTWARE CONTROL

6.1. CONTROL INTERFACES

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

- Through Ethernet connection using SNMP protocol
- GSM interface for circuit switched data calls and SMS sending
- Packet-switched interface for TCP/IP connection via BHE NMS through 2G/4G modem

6.2. 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

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.

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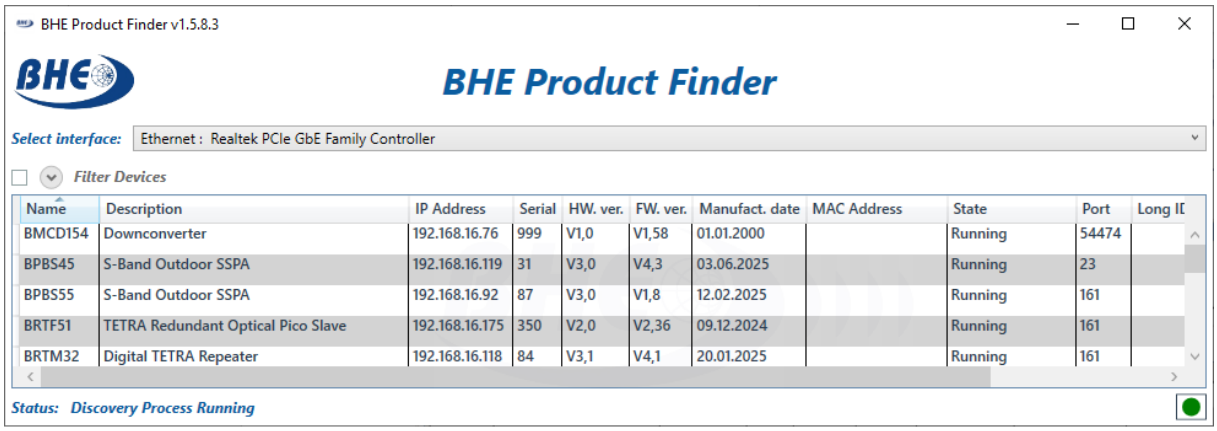

The following ports are used by the device:

- 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.

6.3. SNMP OPERATION

6.3.1. GENERAL CONSIDERATIONS

The repeater uses SNMPv1, SNMPv2c or SNMPv3 (on user request) 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 number than the configured value will be ignored by the device.

In case of SNMPv3, parameters can be monitored and changed by accessing SNMP objects with a valid username and password.

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.

When controlling through MIB browser the appropriate MIB file should be loaded in the browser. Requesting an object that doesn't 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. Precautions are advised.

The repeater can send traps not only in case of failure but also during normal operation. These periodical 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.

6.3.2. USER MANAGEMENT

The device supports SNMP protocol versions v1, v2c and v3. SNMP v3 offers authentication and encryption functionality, providing safe access to devices. The device implements 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 device supports SHA-1 authentication, and optional AES encryption. Note that MD5 authentication and DES encryption are not supported.

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:

- volatile

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

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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

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

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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 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 device supports up to 5 users besides the 2 permanent template users (which can also be used).

6.3.3. 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 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.

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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 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 usable.

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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.

6.3.4. 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.

6.3.5. SNMP CONTROL

The repeater can be monitored and controlled using SNMP protocol. To support this functionality, BHE provides a MIB file that can be imported by software designed for SNMP operations (called MIB browsers).

Note that the device has a common MIB file with several different device types. The reason for this is that BHE MIB files are applicable to entire device families. The name of the MIB file is usually the type name of the first SNMP-capable device of the family. The MIB file for the device is called BRTL36.mib.

Note that some parameters found in the MIB file might not be supported by the device.

After importing the correct 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"

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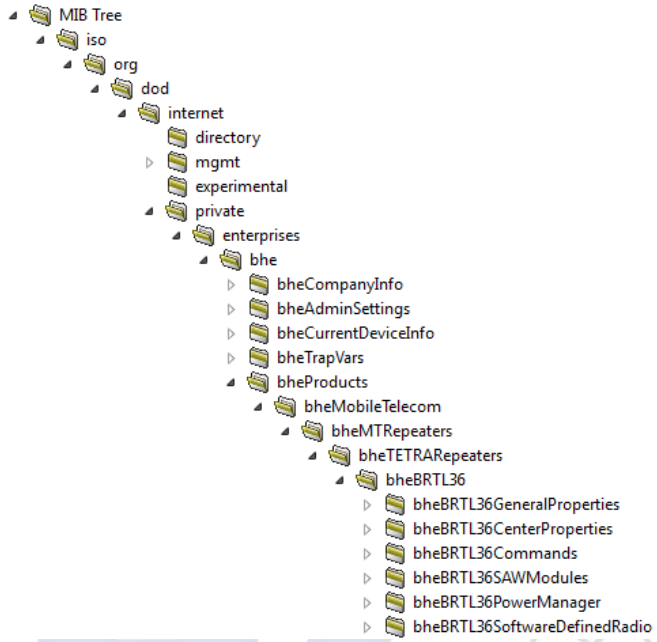
represents a parameter that can be queried and/or set. The BRTL36 MIB tree (which is applicable to the device) is shown in the following image, opened to the bheBRTL36 node.



BHE MIB files have two parts: a part common to every BHE MIB file that contains 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 that following nodes:

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

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. bheAdminSettings has four child nodes: bheNetworkProperties, bheFactoryCommands, bheModemParameters and bheDebug.

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

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bheCurrentIP returns the current IP address of the device. bheMACAddress returns the MAC address of the device. The bheDefaultIP, bheIPMask, bheDHCP and bheIPGateway leaves can be used to query and set basic network properties. bheDiscoveryEnabled determines whether the device will appear in BHE Product Finder. Disabling this feature makes it more difficult for an attacker to discover the IP address of the device. Note that it is necessary to restart the device for these changes to take effect. The device can be restarted using the bheBRTL36Restart 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. When using SNMPv2, the device will only accept read commands that match one of the read community names and 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 section Alarm Reporting.

The bheFactoryCommands node contains the bheSetFirmwareUpgradeMode and bheRestartDevice 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 is complete, the device restarts automatically with the new firmware. If no firmware download occurs within two minutes, the device restarts and returns to normal operation with no change to the firmware.

The device can be restarted using the bheRestartDevice leaf.

bheRebootWithFirmwareSelection enables easy firmware rollback functionality. It is possible to boot into an earlier version of the firmware, if present, by writing to this leaf.

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.

bheDebug contains various debugging functionality. It is usually not necessary to change these settings.

The device specific part of the MIB file can be found under bheProducts -> bheMobileTelecom -> bheMTRepeaters -> bheTETRARepeaters -> bheBRTL36. This node contains six child nodes: bheBRTL36GeneralProperties, bheBRTL36CenterProperties, bheBRTL36Commands, bheBRTL36SAWModules, bheBRTL36PowerManager and bheBRTL36SoftwareDefinedRadio. The general properties node contains general information about the device, such as type, serial number, software version number and manufacturing date. The device also has an identifier field (called Remark

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in the control program) that can be set here using the bheBRTL36Iden leaf. This parameter is a string of at most 64 characters. Special characters can be used; however, the maximum length of the string might be shorter in this case because characters might need to be encoded on several bytes.

bheBRTL36CenterProperties contains information about the center module of the device, as well as user settings. These include measured parameters (supply voltage and current values), various status information (RF power status, muting status), alarm settings (including external alarms), and general settings that concern the functionality of the entire device (RF power switch, adaptive gain, muting).

Alarm conditions can be monitored using the leaves in the bheBRTL36CenterAlarm node. Here, the bheBRTL36CenterAlarmMom leaf contains the momentary alarm states of the device. There are 30 possible alarm conditions, though not all of them are used by the device. 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 bheBRTL36CenterAlarmLatch field is necessary for SMS error reporting. Since the device does not have an embedded GSM modem, the value of this leaf is arbitrary and should be ignored by managers. Its use in SMS error reporting is that 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 of time.

bheBRTL36CenterAlarmTrapMask and bheBRTL36CenterAlarmDryContactMask allow setting the trap and dry contact masks of the device respectively. A bitwise AND operation is performed on the momentary alarm values of the device and the mask, and the result determines if the device needs to signal an alarm by trap message, or dry contact. Therefore, if the mask bit corresponding to a specific alarm is 1, alarm signaling for that alarm condition is enabled. The bheBRTL36CenterAlarmDryContactPolarity leaf allows the user to set the dry contact polarity (active open or active closed).

Leaves in bheBRTL36CenterExternalAlarmTable allow setting the polarity and name of external alarms.

The bheBRTL36Commands node contains the "save initial values", "recall initial values" and "recall factory values" commands. Writing to these leaves will make the device save momentary values as initial, recall initial values or recall factory values.

The bheBRTL36SAWModules node contains information and user settings about the SAW modules of the device. bheBRTL36SAWModuleUplink and bheBRTL36SAWModuleDownlink contain uplink and downlink parameters, respectively.

The two SAW modules have some common properties that can be found in both and uplink and downlink side. These include the following read-only values and measured parameters: the connection status of the module, version number, synthesizer lock status, temperature, overdrive status, overdrive level (in dBm), forward power monitor value (in dBm), module current and supply voltage, and ALC regulating voltage (the overdrive level in volts).

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Common uplink and downlink user settings include ALC level, gain, overdrive protection and frequency value.

Downlink specific user settings include low power alarm parameters.

The contents of the bheBRTL36PowerManager node are not applicable to the device, as it does not possess a programmable power manager module.

The contents of the bheBRTL36SoftwareDefinedRadio node are not applicable to the device, as it does not possess an SDR module.

6.3.6. ALARM REPORTING

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

- SNMP trap messages (protocol version selectable)
- Front LED
- SMS messages (optional)

Alarm reporting using trap messages

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

The following steps need to be taken to enable trap sending using a MIB browser:

1) Access the device using a MIB browser. Navigate to node bheAdminSettings->bheNetworkProperties->bheSNMPSettings in the MIB file.
2) Set the IP address of the computer that should receive the traps in the bheTrapAddress leaf of bheTrapTable.
3) Enable trap sending to this address using the bheTrapEnable leaf in the same table.
4) If using SNMPv3 traps, set bheTrapCommunity to a valid username. Note that trap messages can be sent to up to five different managers. If traps need to be sent to more than one manager, repeat steps 2 - 4 as necessary.
5) Set the trap sending interval 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.
6) Enable trap sending globally using the bheGlobalTrapEnable leaf in bheSNMPSettings.
7) Configure trap masks as needed by setting bheBRTL36CenterAlarmTrapMask in bheBRTL36CenterProperties -> bheBRTL36CenterAlarms.

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Alarms in the device are indicated by the bheBRTL36CenterAlarmMom leaf (short for Alarm, Momentary). Each bit indicates a possible alarm condition in the system. For a description of what sort of error the individual alarm bits indicate, refer to section Alarm Reference, or see the MIB file.

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 device contain the following information:

- System uptime (how long the unit that sent the trap has been running)
- Trap OID (this is always the OID of bheBRTL36CenterAlarmMom)
- Device status. 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. The device left "operates correctly" state and entered "alarm" 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 since the previous trap message. 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.
- Trap mask of the device.
- Momentary alarm values of the device.
- Type of the device.
- Serial number of the device.
- Remark string of the device.

The device 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.

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Alarm reporting with traps example

A unit has a supply voltage alarm and is configured to send trap messages every 15 seconds. Tamper alarm 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	Device sends trap with alarm value = 00 00 00 20h (supply voltage alarm is active)
0s	Trap timeout is reset (next trap will be sent after 15s)
3s	Device notices active tamper alarm
3s	Device sends trap with alarm value = 00 00 00 30h (supply voltage and tamper alarm active)
3s	Trap timeout is reset (next trap will be sent after 15s)
18s	Device sends trap with alarm value = 00 00 00 30h (supply voltage and tamper alarm active)

Front LED alarm indication

The front LED of the device will be continuously lit during normal operation. If any alarm condition occurs, the front LED will start blinking.

SMS alarm reporting

SMS alarm reporting functions similarly to trap sending, in that the device will attempt to send an SMS message about changes in its alarm state as soon as possible.

Unlike alarm signaling through trap messages, however, an SMS might not be sent immediately. The device implements three user-defined time intervals to control when SMS messages will be sent. The minimum interval determines how much time has to pass between two consecutive messages. No new message will be sent before this timeout elapses, even if the active alarms of the device have changed.

The second user-defined time interval is the alarm repetition interval. This interval determines when messages about alarms are repeated if the device is in alarm state (i.e. has one or more active alarms for which SMS sending is enabled), but its alarm have not changed compared to the last message.

The third user-defined time interval is the heartbeat interval. Heartbeat messages are sent periodically at this interval when the device has no active alarms for which SMS sending is enabled. Heartbeat messages can also be disabled altogether.

For a detailed description of the protocol used in SMS sending, contact BHE.

6.3.7. 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 (note that the device supports only SNMP monitoring)
    - SNMP monitoring
    - SMS reception using a GSM modem
    - GPRS connection using a GSM modem
- Repeater control via different interfaces (note that the device supports only SNMP control)
    - 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 device. By importing the MIB file other network managers can monitor BHE devices.

The simplest way to monitor the status of BHE devices is to query their so-called AlarmMom (short for "Alarm, momentary") parameter. Every BHE device possesses a parameter like this. The integer value returned when it 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 section Alarm Reference or the description of the AlarmMom variable in the MIB file.

Generally, either 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.

6.3.8. ALARM REFERENCE

Alarm conditions of the device can be monitored by querying the bheBRTL36CenterAlarmMom parameter in the MIB file. The following alarm conditions are monitored by the device:

Alarm Table

BIT0	External Alarm 1 (some devices)
BIT1	External Alarm 2 (some devices)
BIT2	External Alarm 3 (some devices)
BIT3	External Alarm 4 (some devices)
BIT4	Tamper (some devices)
BIT5	Supply Voltage
BIT6	Supply Current
BIT7	Fan Error (some devices)
BIT8	Modem (optional)
BIT9	Downlink Low Power
BIT10	Uplink Supply Voltage
BIT11	Downlink Supply Voltage
BIT12	Uplink SAW Current
BIT13	Downlink SAW Current

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BIT14	Uplink PAM Current (some devices)
BIT15	Downlink PAM Current (some devices)
BIT16	Uplink Overdrive (over 30 min)
BIT17	Downlink Overdrive (over 30 min)
BIT18	Reserved (always 0)
BIT19	Downlink Overpower (some devices)
BIT20	Reserved (always 0)
BIT21	Downlink VSWR (some devices)
BIT22	Uplink Temperature
BIT23	Downlink Temperature
BIT24	Uplink Synthesizer Unlocked
BIT25	Downlink Synthesizer Unlocked
BIT26	Uplink Overdrive Level
BIT27	Downlink Overdrive Level
BIT28	Low Battery Voltage (some devices)
BIT29	Low Main Supply Voltage (some devices)

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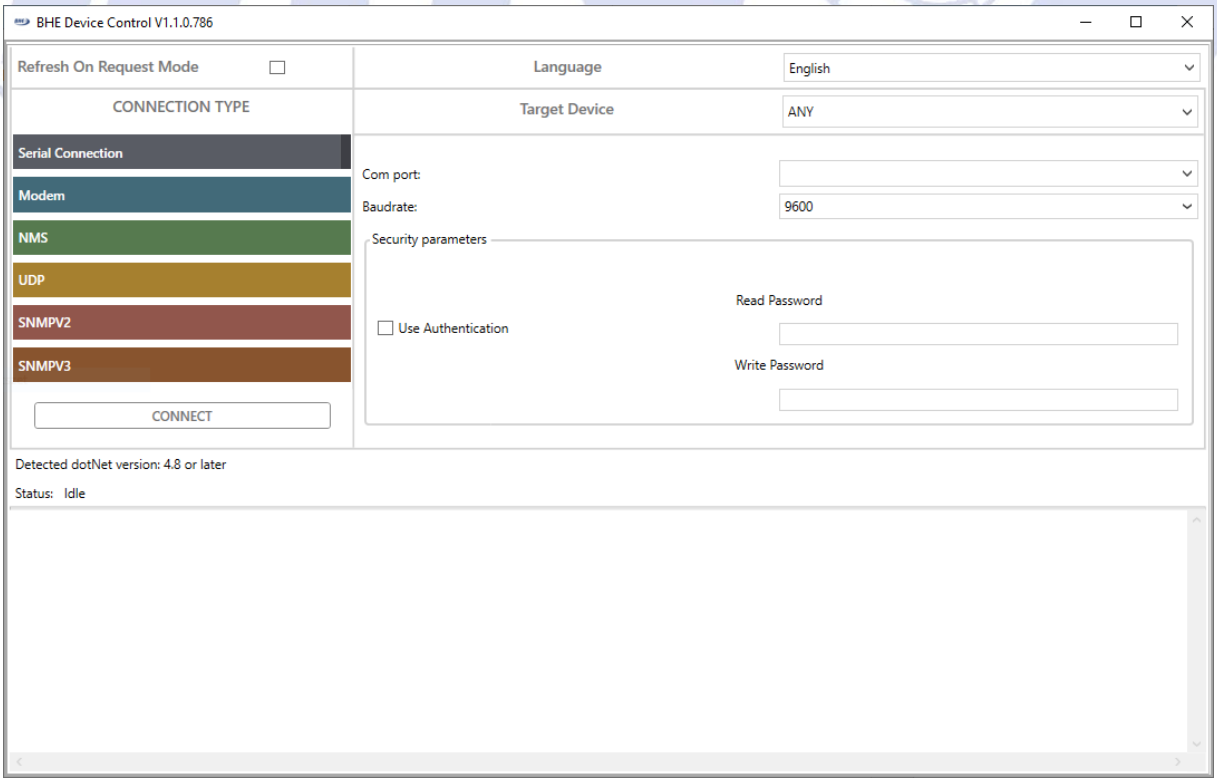
7.4 USAGE OF THE BHE DEVICE CONTROL PROGRAM

7.4.1. MINIMUM SYSTEM REQUIREMENTS

- Dual core processor
- 2 GB RAM
- 100 MB hard disk capacity
- Microsoft Windows operating system with .NET Framework 4.8 (or higher)

7.4.2 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.



BHE Device Control Connection Selector

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

- Serial Connection: Connection to a repeater through RS232 serial port.
- Modem: Connection to a repeater through 2G/4G modem, using CSD call.
- NMS: Connection to a repeater through the BHE NMS Server, over 4G network.
- UDP: Connection to a repeater through UDP over Ethernet network.
- SNMPv2: Connection to a repeater through SNMPv2 protocol over Ethernet network.
- SNMPv3: Connection to a repeater through SNMPv3 protocol over Ethernet network (available on user request).

When selecting SNMPv3 control, the user should enter values for the username, authentication key, privacy key fields and select the proper authentication and privacy protocols.

The IP Address can be determined using the BHE Product Finder program which detects and lists BHE devices connected to the network (see chapter Ethernet Interface for more details).

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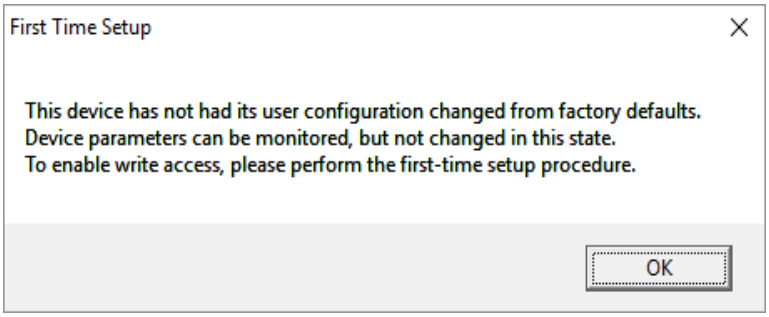
7.4.3. FIRST-TIME SETUP

The control program warns the user if the device still has factory default security settings and navigates to the "User Management" tab.



First Time Setup Message

The following steps need to be followed to perform the first-time setup procedure and enable write access to the device. For a detailed description of the first-time setup procedure, see chapter First-time Setup.

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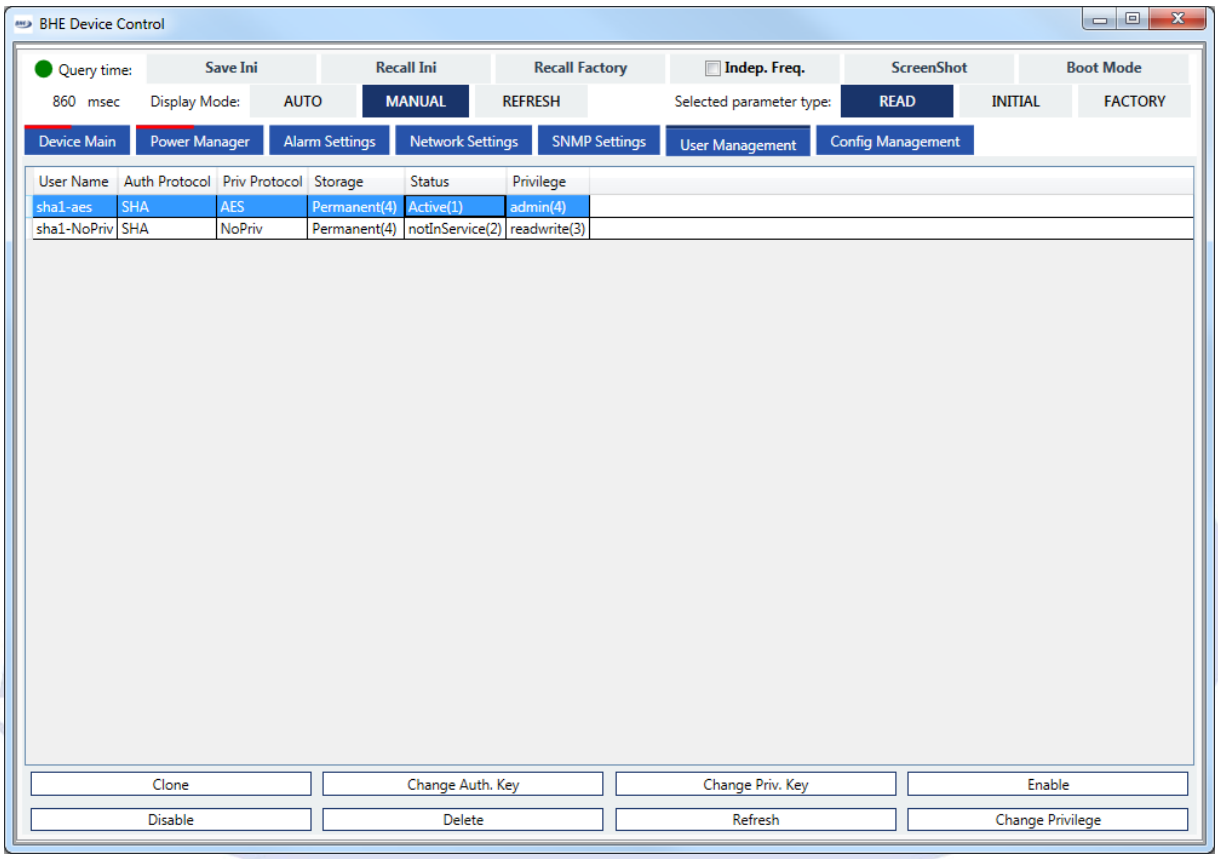
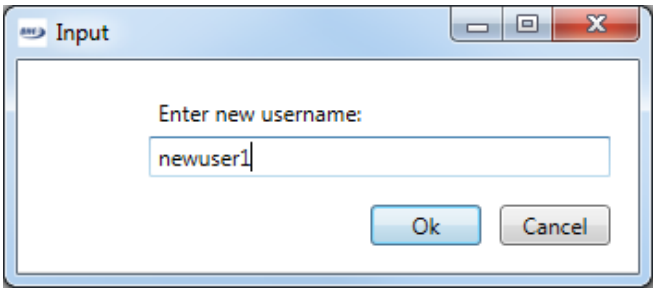
Create new user:

To create a new user, press the "Refresh" button and select an existing user with administrator privilege from the list, then press the "Clone" button. The authentication and privacy settings of the selected user will be copied over to the new user. This includes authentication and privacy protocol type, as well as passwords.



Enter the desired username for the new user in the Input dialog and press the "Ok" button:



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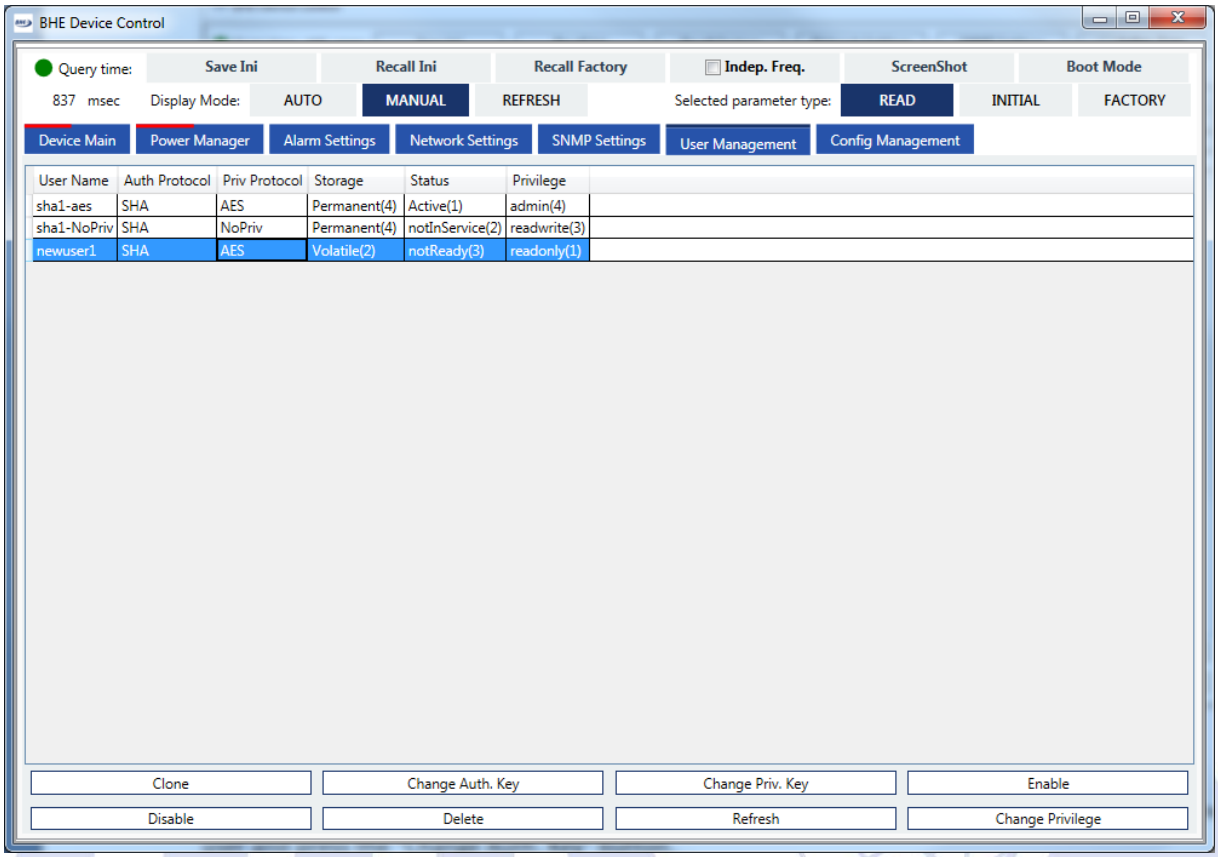

The new user will appear in the list. Its status will be "notReady".

Authentication and Privacy keys must be changed after the user is created. Select the new user and press the "Change Auth. Key" button.

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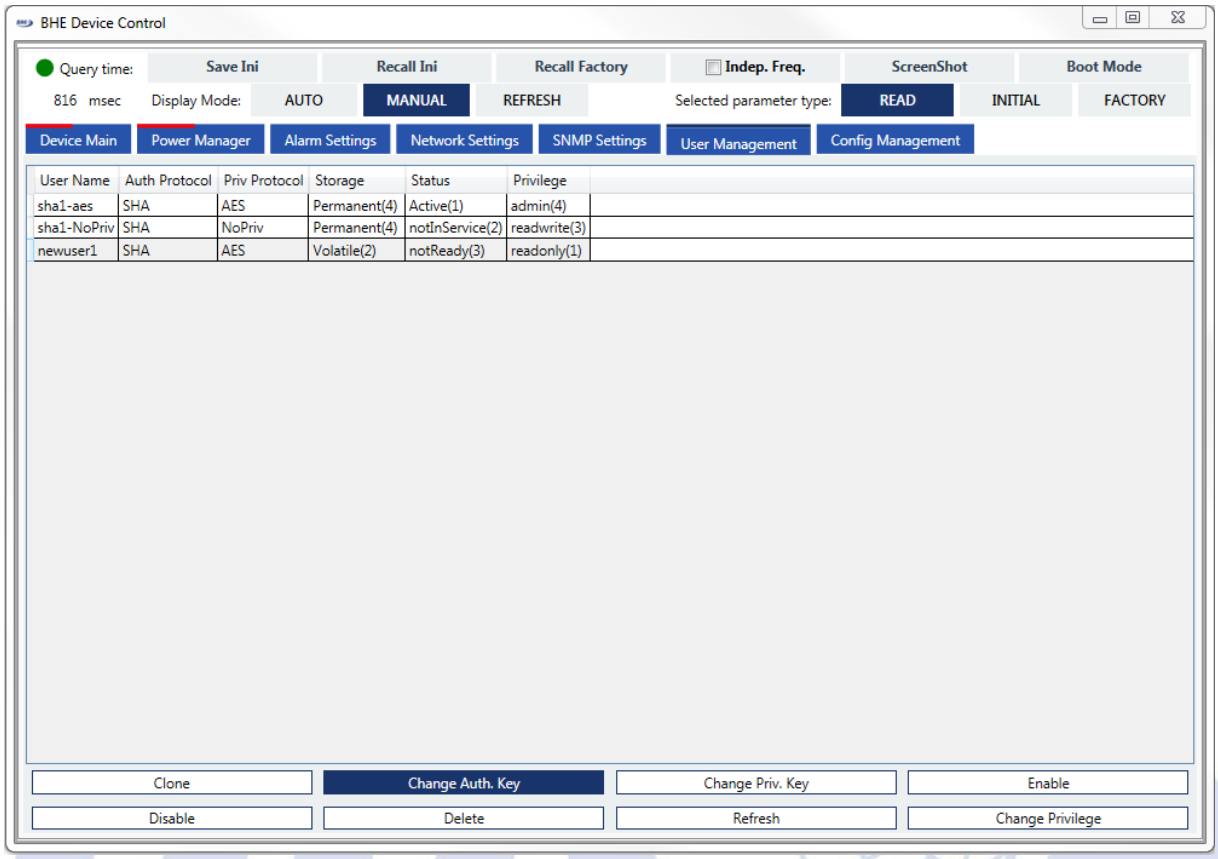
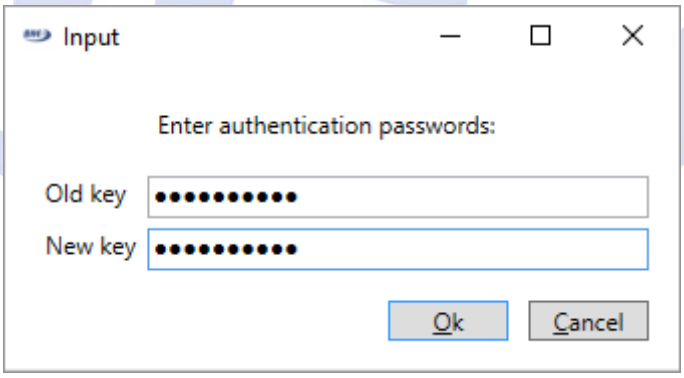


Enter the "Old key" (authentication key of the cloned user) and "New key" values and press "Ok".



Select the new user and press the "Change Priv. Key" button.

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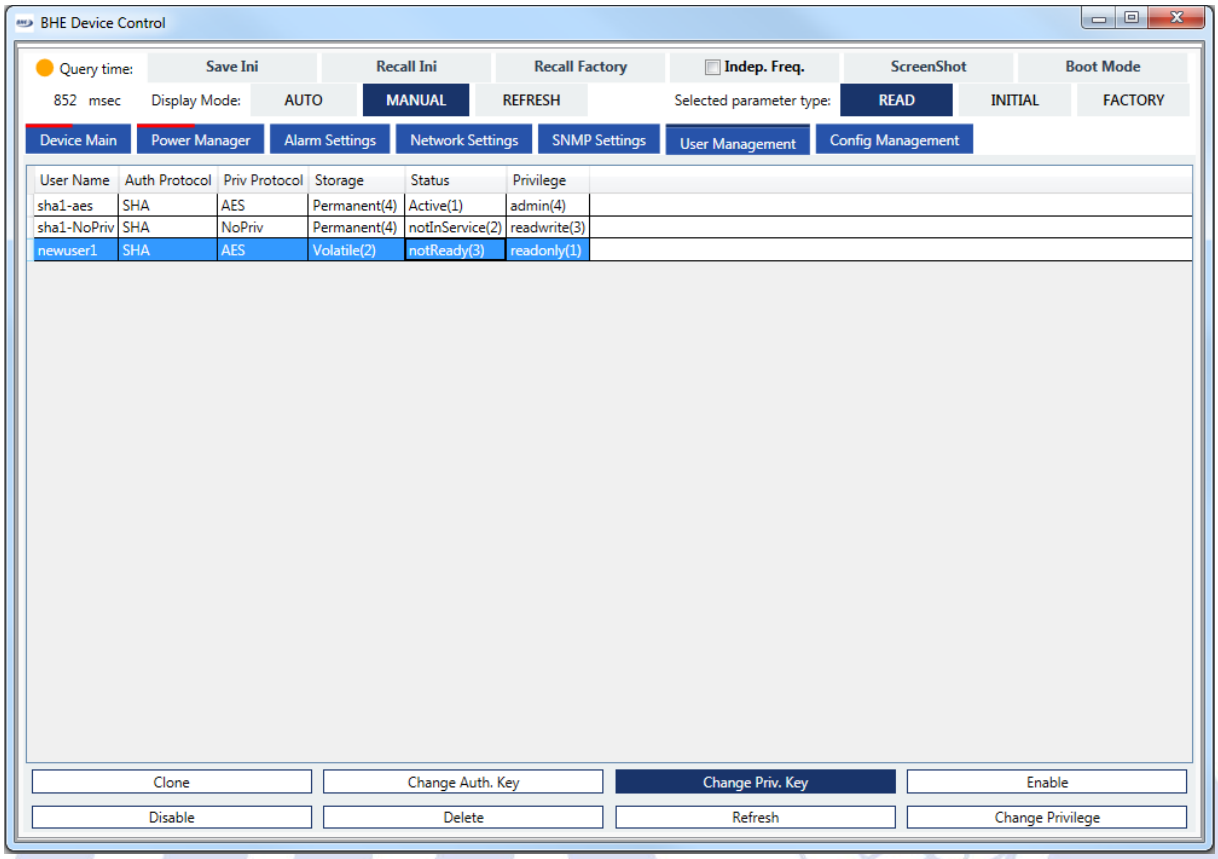
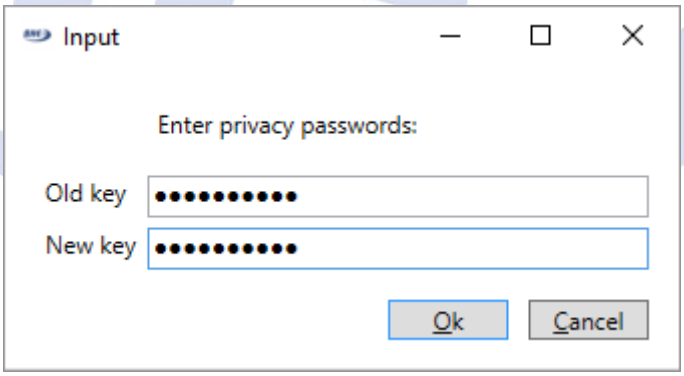


Enter the "Old key" (privacy key of the clone source user) and "New key" values and press "Ok".



If the passwords are correct, the new user's state changes to "notInService".

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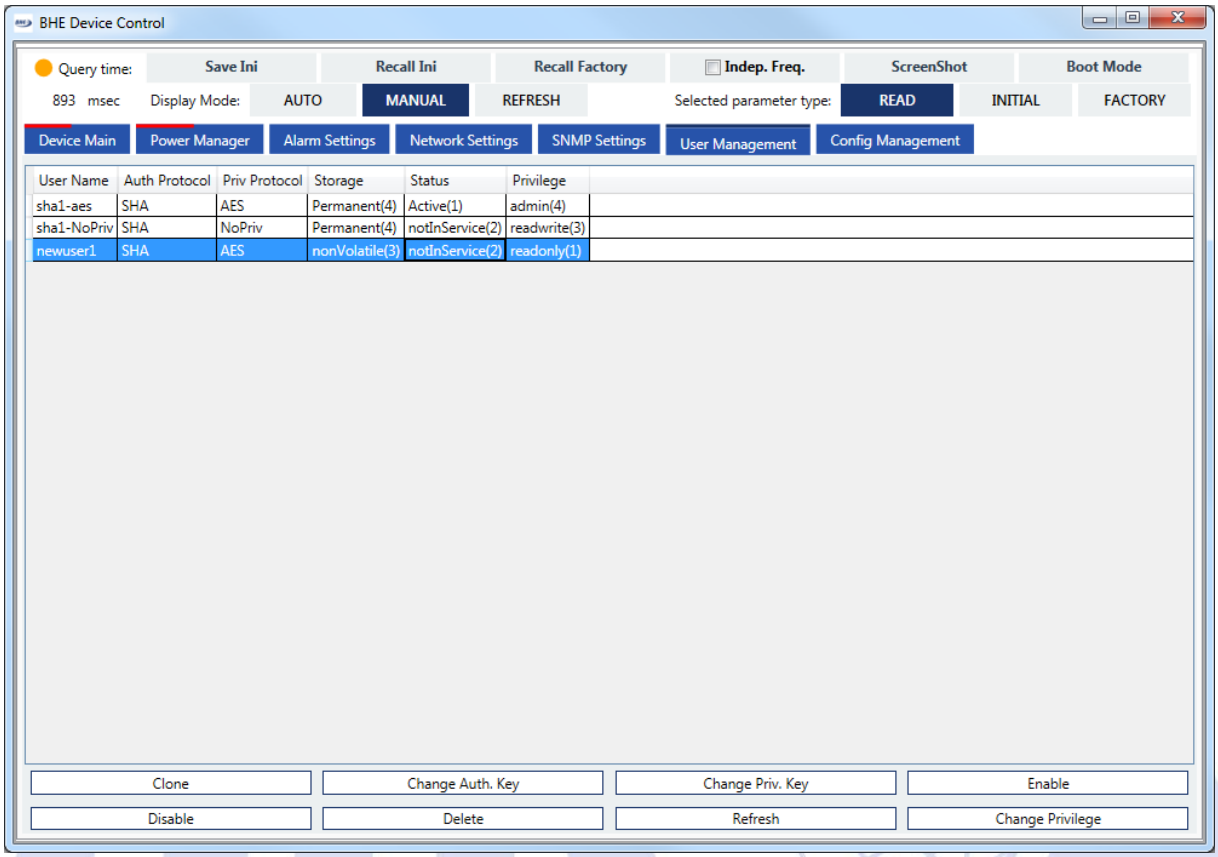

To activate the user, select it and press the "Enable" button.

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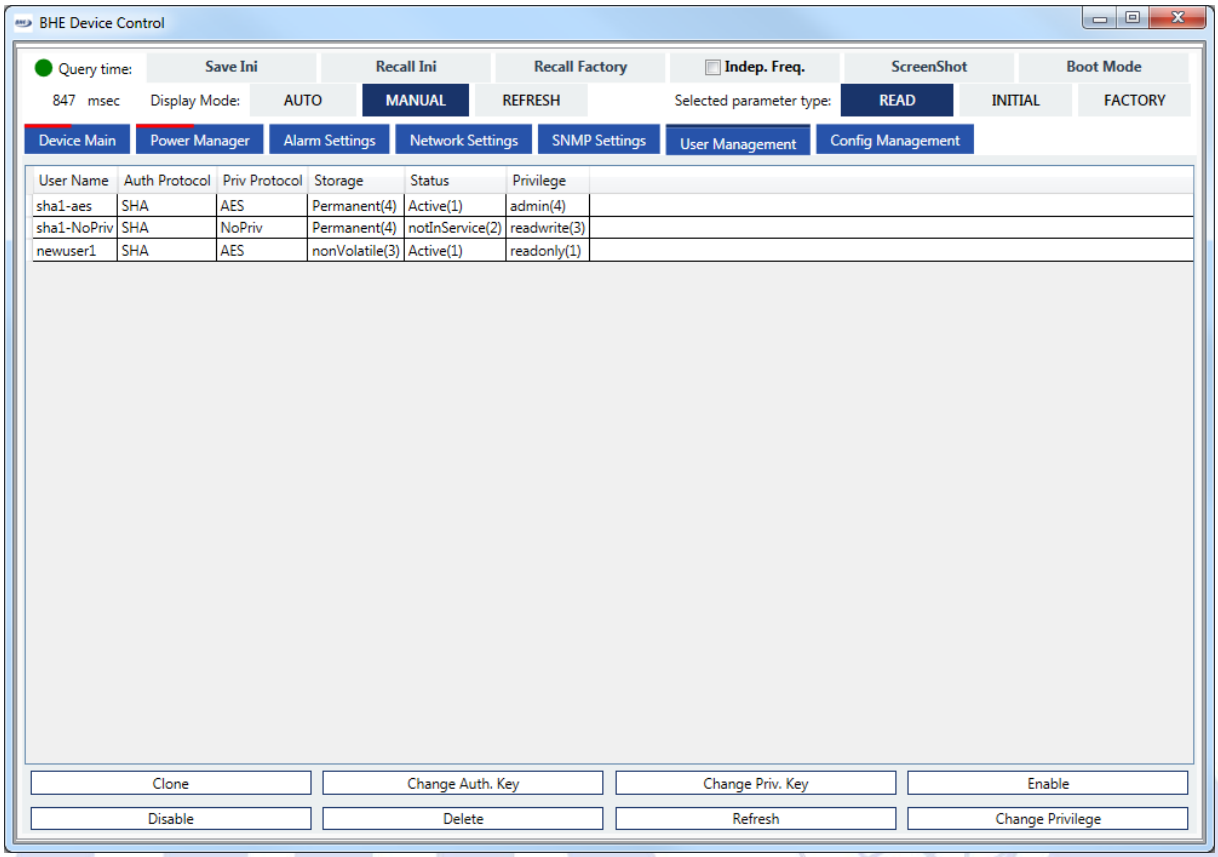
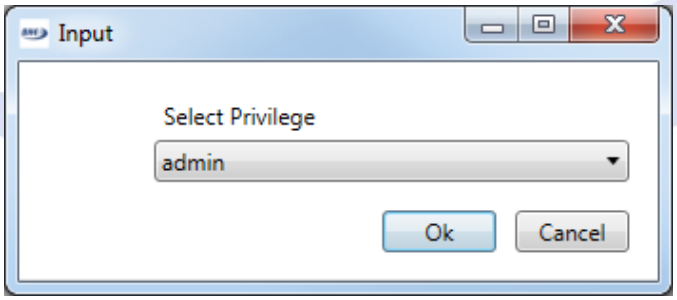


By default the new user's privilege is read-only. Use the "Change Privilege" button to elevate the user to admin privilege:



After a new administrator user has been created, disable the two template users to complete the first time setup process.

New users can be added by logging in with an administrator account and following the procedure above.

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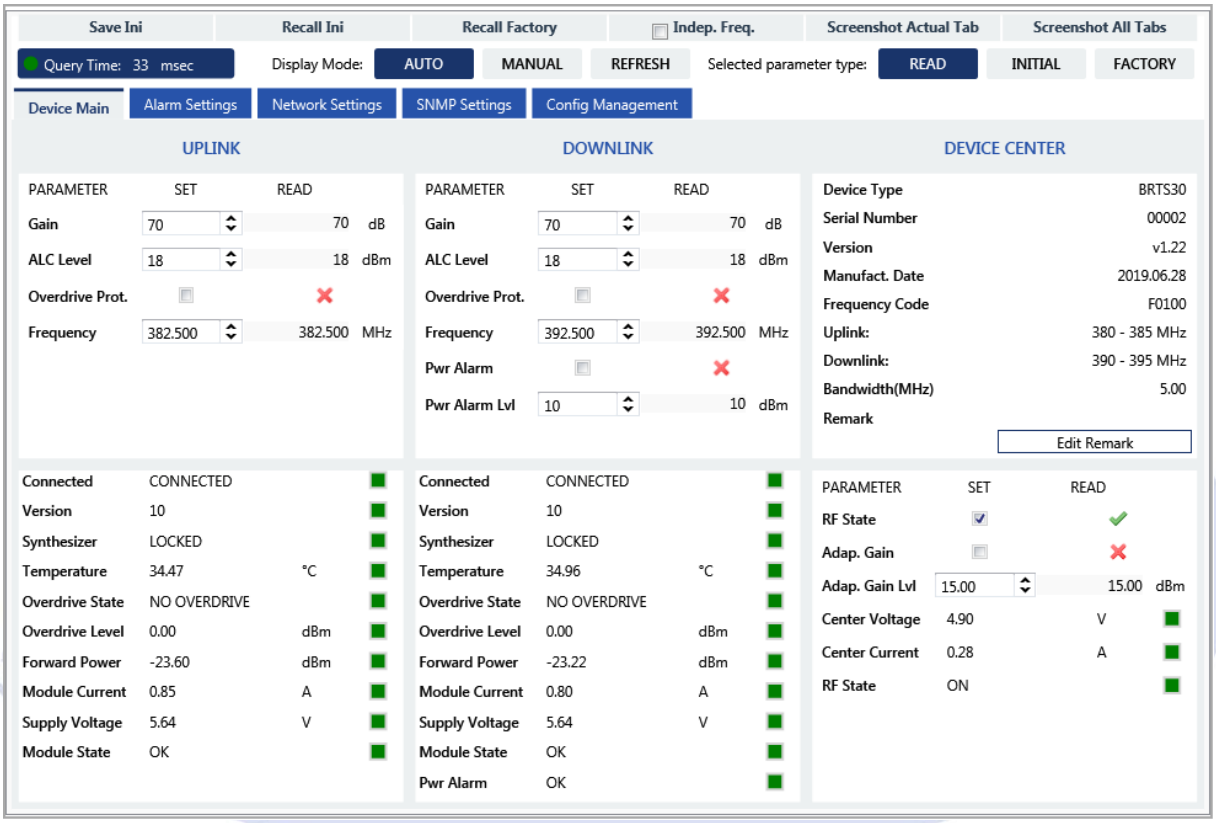
7.4.3 OVERVIEW OF THE MAIN WINDOW

After establishing a 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 and the list of tabs containing the device parameters.



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 set to the initial values. Momentary values can be saved as 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.

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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 control groups:

- Menu buttons – Contains miscellaneous functions: Recalling/saving initial values, enabling independent uplink and downlink frequency settings, taking screenshots and putting the device in bootloader mode.

  - Save Ini: The momentary (READ) values of the controlled parameters will be saved as INI (initial) values.
  - Recall Ini: The controlled parameters will be set to values that were previously saved to ini values.
  - Recall Factory: The controlled parameters will be set to values that were set in the factory during manufacturing.
  - Indep. Freq: Not applicable in the device.
  - Screenshot Actual Tab: Saves a screenshot of the current tab, as it momentarily appears.
  - Screenshot All Tabs: Saves a screenshot of all tabs, as they momentarily appear.

- 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 overridden by the value read back from the device ('READ' value).
  - Manual mode: The ‘SET’ and ‘READ’ values are not synchronized automatically.
  - Refresh: Immediately perform synchronization of the ‘SET’ and ‘READ’ values.

- Selected parameter type

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

- Parameter tabs
  Device parameters grouped by functionality.

Device Main: Uplink, Downlink and Center module parameters.
Alarm Settings: Trap and dry contact masks.
Network Settings: Various IP parameters, such as default address, DHCP operation, gateway address and net mask.
SNMP Settings: Various SNMP parameters, such as minimum accepted SNMP version and trap settings.
Config Management: Saving and loading report and configuration files.

At the top of the Device Main tab, a small red line may appear. This is used to indicate that the device has some sort of error. The error indication disappears when the error ceases.

An orange line at the top of the tab control indicates inconsistent 'SET'-'READ' value pair(s) in the parameter group. This indication can appear on the Device Main, Network Settings and SNMP Settings tabs. When the discrepancy between user settings and read-back values ceases, the orange indication also disappears.

Monitored parameters each have their own alarm indication. A green square near the data means the value is within allowed range or the parameter is correct, while a red square indicates failure of the parameter.

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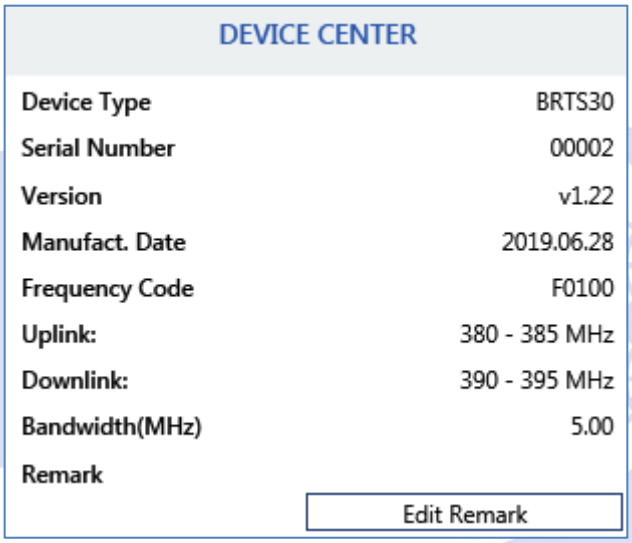
7.4.4 DEVICE MAIN TAB

The Device Main tab contains uplink, downlink and device center module parameters.

Center Module Parameters

- Device Center manufacturing information – The upper right part of the "Device Main" tab displays manufacturing information and center module parameters of the accessed device.



  - Device Type: The type of the device.
  - Serial number: The serial number of the device.
  - Version: The firmware version number of the device.
  - Manufact. Date: The manufacturing date of the device (in YYYY.MM.DD format).
  - Frequency Code: Uplink/Downlink frequency identifier.
  - Uplink: The uplink frequency band.
  - Downlink: The downlink frequency band.
  - Bandwidth: Bandwidth of the current device.
  - Remark: Text field that can be edited by the user. Useful for setting a string that uniquely identifies the device.

- Device Center parameters – The lower right part of the "Device Main" tab displays the monitored and controlled parameters of the center module of the accessed device. Both the momentary (Read) and the power up (Ini) values of the controlled parameters are displayed.

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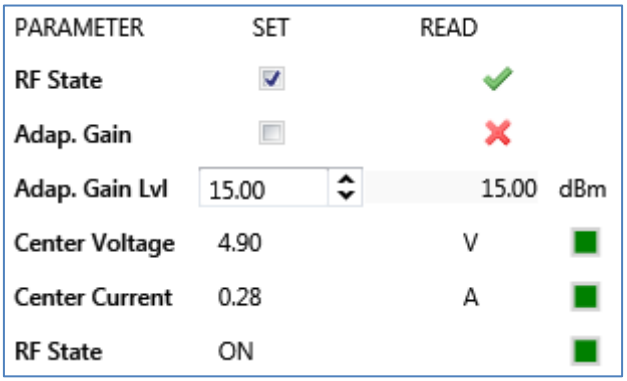
Monitored parameters within normal operating range have a green square next to them while parameters out of normal operating range have a red colored square.



- RF State: Turn RF transmission on or off.
- Adaptive Gain Enable: Enable/disable adaptive gain functionality. The operation of this function is detailed later in this chapter in section Special Device Functions.
- Adaptive Gain Level: Set desired downlink forward power value for the adaptive gain function (1 dBm step).
- Center Voltage: Measured value of the supply voltage of the center module.
- Center Current: Current consumption of the center module.
- RF State: Momentary state of the RF Stage (ON/OFF).

The green square near monitored parameters means the value is within range or the parameter is correct while red square indicates failure of the parameter.

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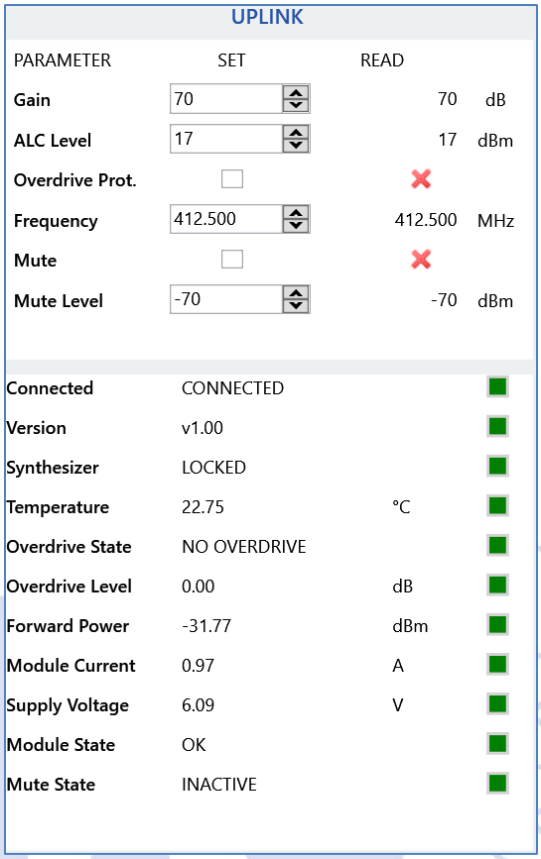
Uplink Parameters



The left part of the Device Main tab shows parameters related to the uplink module of the device. The device supports control of the following parameters:

- Gain: The uplink gain can be set in the range indicated in the product datasheet at 1 dB step.
- ALC level: The ALC level can be set in the range indicated in the product datasheet range 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 this function is detailed later in this chapter in section Special Device Functions.
- Frequency: Set the uplink frequency.
- Mute: Enable/disable the mute function. The operation of this function is detailed later in this chapter in section Special Device Functions.
- Mute Level: Threshold level of the mute function.

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The lower left part of the Device Main tab shows uplink module monitored parameters. The following parameters are shown:

- Connected: Module connection state (CONNECTED / NOT CONNECTED)
- Version: Firmware version of the module.
- Synthesizer: Indicates lock status of PLL circuits of the module. In case of correct operation, this parameter reads LOCKED. UNLOCKED state indicates an error.
- Temperature: Module temperature in °C.
- Overdrive State: Indicates whether the module is overdriven. More details about overdrive indication can be found later in this chapter in section Special Device Functions.
- Overdrive Level: Shows the level of overdrive in dBm units.
- Forward Power: Forward power measured in dBm.
- Module Current: Current consumption of the module.
- Supply Voltage: Indicates module supply voltage.
- Module State: Indicates the status of the uplink module.
- Mute State: Indicates whether uplink transmission is muted.

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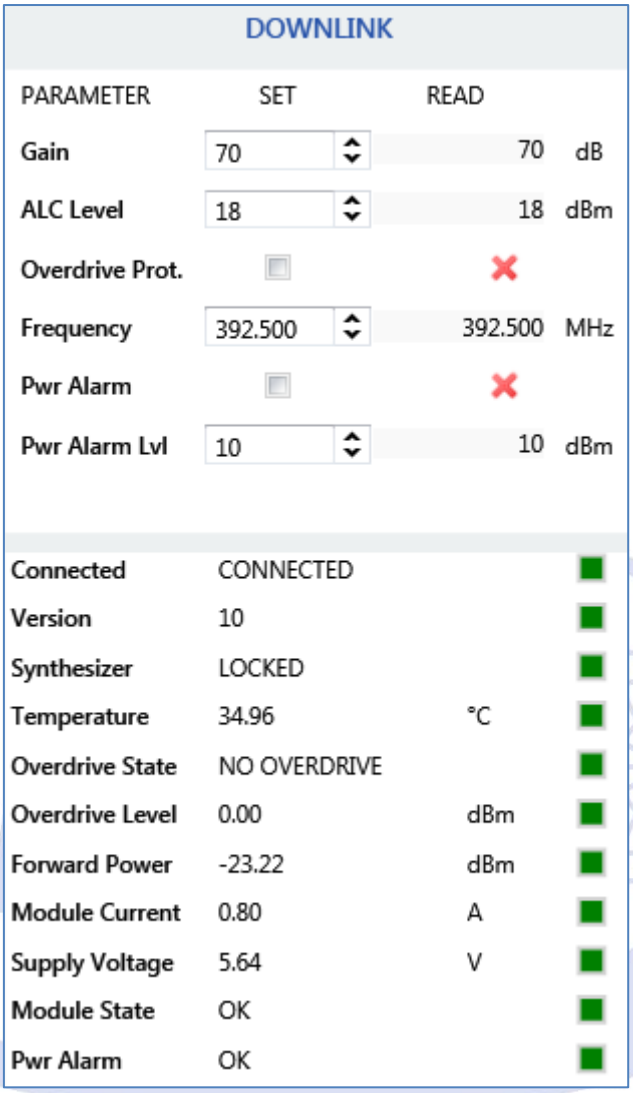
Downlink parameters



The middle part of the Device Main tab shows parameters related to the downlink module of the device. The device supports control of the following parameters:

- Gain: The gain can be set in the range indicated in the product datasheet at 1dB step.
- ALC Level: The ALC level can be set in the range indicated in the product datasheet at 1dBm 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 this function is detailed later in this chapter in section Special Device Functions.
- Frequency: Set the downlink frequency.

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- Pwr Alarm: Enable/disable downlink low power detection.
- Pwr Alarm Lvl: The alarm threshold level that the downlink RF power is compared to. If downlink low power detection is enabled and the downlink RF power is lower than this value for about a minute, the downlink RF power is considered to be incorrect and an alarm is generated (see section Alarm Reference for a description of possible alarms).

The lower middle part of the Device Main tab shows downlink module monitored parameters. The following parameters are shown:

- Connected: Module connection state (CONNECTED / NOT CONNECTED)
- Version: Firmware version of the module.
- Synthesizer: Indicates lock status of PLL circuits of the module. In case of correct operation, this parameter reads LOCKED. UNLOCKED state indicates an error.
- Temperature: Module temperature in °C.
- Overdrive State: Indicates whether the module is overdriven. More details about overdrive indication can be found later in this chapter in section Special Device Functions.
- Overdrive Level: Shows the level of overdrive in dBm units.
- Forward Power: Forward power measured in dBm.
- Module Current: Current consumption of the module.
- Supply Voltage: Indicates module supply voltage.
- Module State: Indicates the status of the downlink module.
- Pwr Alarm: Momentary state of the power alarm function (OK / ERROR).

Special Device Functions

Overdrive Protection

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

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

Overdrive Level is displayed in dBm units and is calculated from the ALC regulating voltage. If the Overdrive Level is in normal range there is no overdrive. 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 dBm for the device), a momentary overdrive status is indicated. The square near the Overdrive Level changes to red and "Overdrive State" will show "Overdrive". Momentary overdrive does not cause an alarm in the device, meaning that no trap message is sent about it, nor is it indicated by dry contact relay.

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 RF stage 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 RF stages 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)".

If the overdrive still exists the RF stages 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 device is capable of automatically setting its gain appropriately to achieve a desired downlink forward power level.

When adaptive gain is enabled, the gain and ALC level parameters are managed automatically by the device and can no longer be set by the user. The user can influence the adaptive gain operation by setting the Adaptive Gain Target Level. This parameter can also be changed after adaptive gain is enabled. Since when adaptive gain is activated, the device automatically manages gain values to prevent overdrive, overdrive protection cannot be active at the same time as adaptive gain.

After enabling adaptive gain, the device will change uplink and downlink gain values symmetrically to achieve the target downlink forward power.

The adaptive gain function has two modes of operation: fast mode and slow mode.

Fast mode is started in three cases:

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- After power up if the initial value of the adaptive gain function is "ON".
- After the user has switched on the function.
- The adaptive gain target level is changed.

When fast mode is started, both uplink and downlink gain are set to the same value, and the ALC levels are set to the factory default values. During fast mode operation the repeater continuously monitors if there is overdrive or not. The monitoring is performed by checking the overdrive level of the uplink and downlink modules every second. If the overdrive level is lower than the allowed maximum value (6 dBm for the repeater), that is, there is no significant overdrive, the gain of the repeater is increased by 1 dB in both the uplink the downlink modules until the downlink forward power reaches the current adaptive gain target level. If after any increase in gain, the device detects an overdrive condition, the gain is decreased. The increase/decrease of the gain is performed by modifying the attenuator value that is shown in the control software.

The fast mode ends in any of the following cases:

- After the first decrease of gain (or increase if the downlink forward power was above the target level when adaptive gain was started) has been done.
- The target downlink forward power level has been reached.
- The gain has reached the maximal value.

Slow mode operation starts after the fast mode has ended. During slow mode the overdrive level is monitored just like in fast mode. However, in slow mode, the time intervals for increasing or decreasing the gain are different than in fast 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 during the last second or if the downlink forward power is above the target level. Therefore, the maximal gain increase speed is 1dB/minute and the maximal gain decrease speed is 60 dB/minute.

Mute function

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

When the mute function is activated, the device continuously monitors the level of the uplink side input signal. If the RF input power does not rise above the user-defined 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.

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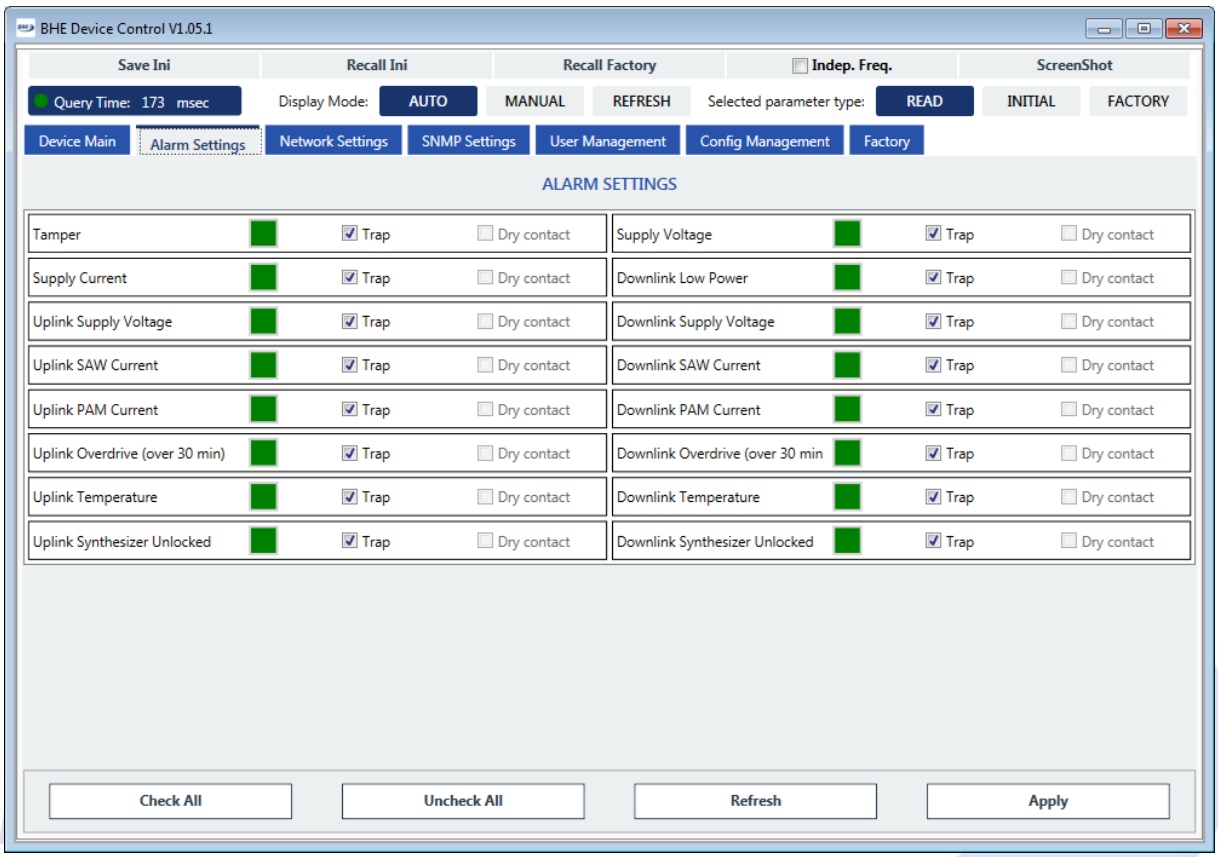
7.4.5 ALARM SETTINGS



Alarm Settings

Under tab "Alarm settings" the user can define the action the device will take for each alarm. This can be either SNMP trap sending or dry contact relay activation.

Failure of a monitored parameter results in an alarm in the system. Most monitored parameters in the device can generate an alarm in case of failure. In the Alarm Settings tab, the user can enable/disable SNMP trap sending and dry contact relay signaling separately for each alarm source. Disabled alarm sources do not take part in trap sending and do not induce dry contact relay activation. Disabling alarm sources does not affect the front panel status LED alarm indication of the repeater.

The colored square next to the parameter name shows the momentary alarm state of the parameter: the squares in this column are colored red if the parameter is outside acceptable limits or colored green if the parameter is within limits. By checking the “Trap” box near the parameter the user can enable the alarm source for SNMP trap sending. By checking the “Dry contact” box the alarm source can be enabled for dry contact alarm signaling.

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

After making the desired settings it can be applied and stored in the device by clicking the "Apply" button. Note that alarm settings are not affected by the Save Ini, Recall Ini and Recall Factory commands. These settings are saved immediately when the user presses the Apply button.

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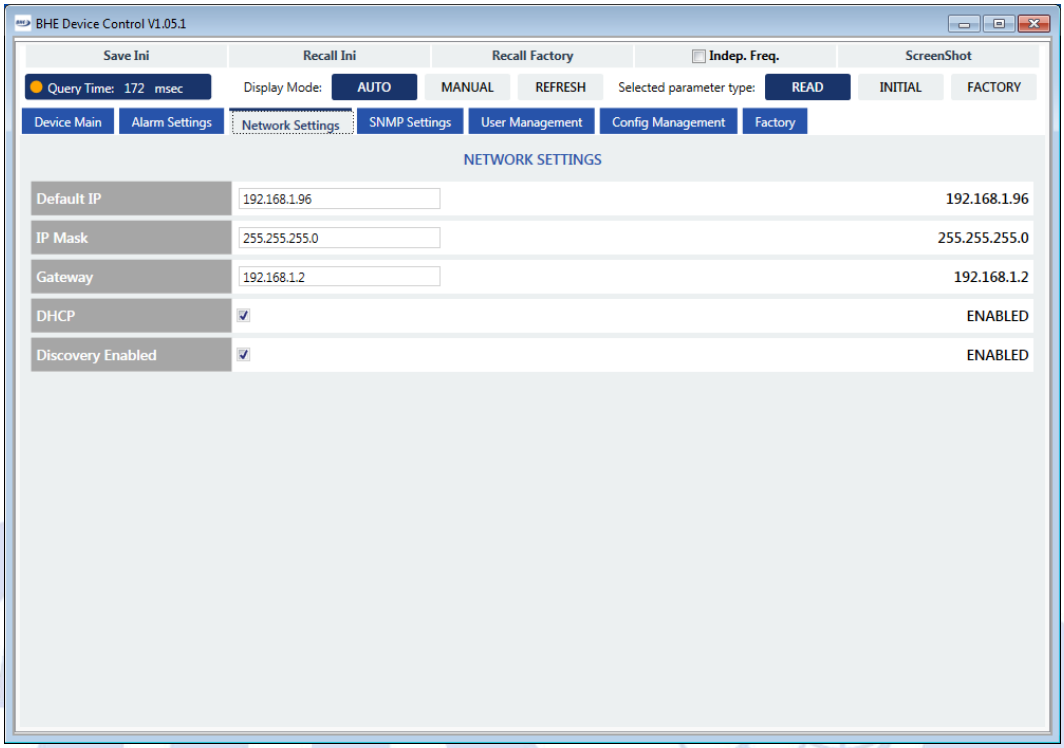
7.4.6 NETWORK SETTINGS



In the Network Settings tab, the user can set the network parameters of the device such as IP Address, IP Mask, Gateway address and DHCP operation. For a description of how these parameters determine the device's IP address, see chapter Ethernet Interface.

Usage of SNMP v3 protocol in the device provides a secure way to access the device (SNMP v3 is optional, based on user request). However, BHE Product Finder uses a different mechanism to find BHE devices on the network. Since this provides a way for potential attackers to find out the IP address of the device, discovery by the 'BHE Product Finder' application can be enabled or disabled.

Note that these settings are saved immediately when they are changed; however, the repeater needs to be restarted for the new settings to take effect.

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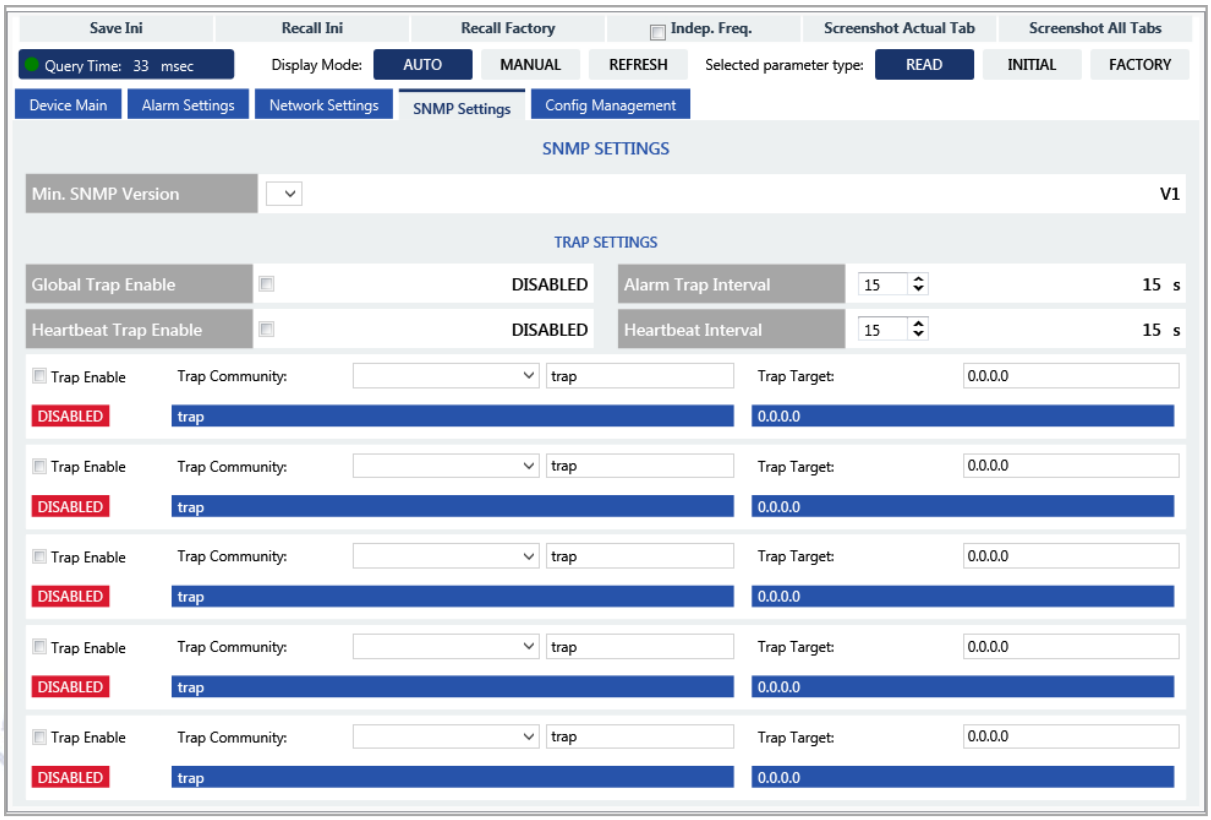
7.4.7 SNMP SETTINGS

The device unit can send SNMP v1/v2c/v3 trap messages (also called notifications) about alarms that occur in the system. The trap sending functionality can be configured in the SNMP Settings tab.



SNMP Settings tab

The following trap 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. 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 in case of failure. Note that this time interval is only applicable

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when the alarms of the device are unchanged. If the alarms change, a new trap message is generated immediately.

- 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 separately.
- Trap Community: The trap community in case of SNMP v1/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.

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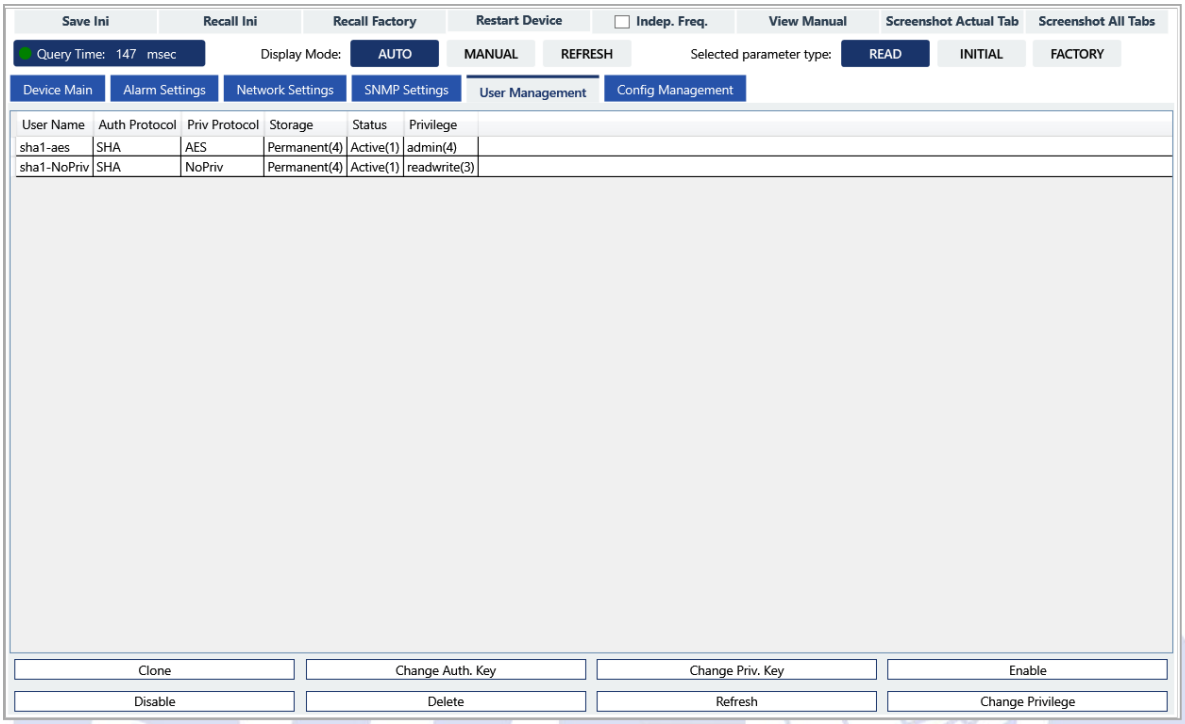
7.4.8. USER MANAGEMENT



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.
- 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.

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- 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.

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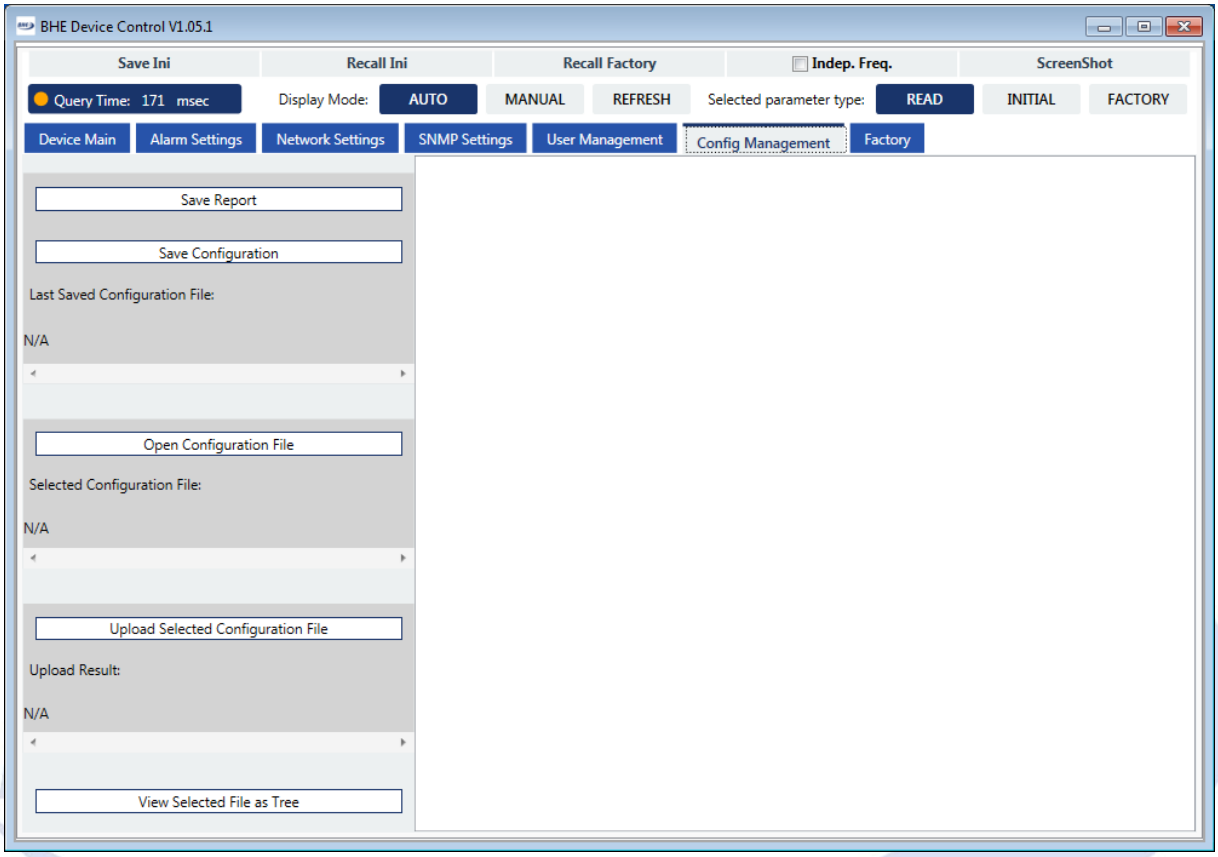
7.4.9 CONFIGURATION MANAGEMENT



The Config Management tab in the control software allows managing the configuration of a single device. Configuration files are saved in human-readable XML format.

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.

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- 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.