

NM3 Acoustic Modem Serial Commands

Hardware V3.2 and V3.4

Firmware 1.6.0

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Introduction

Overview

The NM3 is a low-cost, low-power, miniature acoustic communication and ranging device for underwater vehicles, divers, and subsea instruments. Data messages may be exchanged between units and an efficient "ping" protocol is implemented for range measurement by transponder operation. If multiple units are deployed in known locations, then long baseline positioning (LBL) operation is possible.

Live Document

This draft is a live document and will be added to with information related to the electrical and mechanical specifications.

Contact

For queries and feedback please contact the authors.

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Serial Communications

Serial communication with the modem is possible using RS232 or TTL (2.5V) UART. Both use 9600 baud, 8 data bits, no parity, one stop bit, and no flow control.

All commands issued to the modem are prefixed with '\$' and require no terminating characters.

All responses from the modem are prefixed with '\$' (for a local acknowledgement) or '#' (for the result of an executed command) and terminated with <CR><LF>.

Unrecognised or invalid commands return 'E' to indicate an error.

Serial commands should be sent to the modem as a contiguous string with no more than 2 milliseconds between bytes. If the delay between bytes exceeds this the serial handler will time out and return 'E'.

Modem Commands

\$? – Query Status

Command

\$? requests the modem status.

Response

#A<xxx>V<yyyy>R<aaa>.<bbb>.<ccc>B<YYYY-MM-DDThh:mm:ss><CR><LF> where <xxx> is node address and <yyyy> is an unsigned 16-bit supply voltage monitor value. To convert to a voltage: volts = <yyyy> * 15/65536. R<aaa>.<bbb>.<ccc> is the release using semantic versioning e.g. R001.001.000. B is the build date and time in ISO8601 format.

Example

Local Device

```
> $?  
#A007V21996R001.001.000B2021-12-08T17:05:16<CR><LF>
```

\$A – Set Address

Command

\$A<xxx> sets the modem address where <xxx> is ASCII decimal number between 000 and 255.

Response

#A<xxx><CR><LF> confirms node address has been set to <xxx> and stored in non-volatile memory or **E<CR><LF>** on error.

Example

Local Device

```
> $A007
#A007<CR><LF>
> $A500
E<CR><LF>
```

\$B- Broadcast Data

Command

`$B<xx><data>[T<t*14>]` transmits a message <data> of <xx> bytes to all units within range. Data can be any printable or non-printable byte value. <xx> is the number of transmitted bytes as two ASCII decimal digits (02-64). If the System Timer is enabled, then an optional transmit time can be appended.

Response

`$B<xx><CR><LF>` is returned immediately to confirm <xx> bytes will be broadcast or `E<CR><LF>` on error.

Remote Device

`#B<aaa><yy><data>[Q<zz>D<+ddd>][T<t*14>]<CR><LF>` is produced at the serial output on the receiving modem. Where <aaa> is the transmitting address, <yy> is the number of bytes <data> received. If the Link Quality Indicator is enabled then additional statistics follow with quality, Q, as a number <zz> from 00-99. Doppler tracking is based on the average sample per symbol change over the whole packet. Fractional-sample per sample, $s = \pm \text{ddd} / 1000 \%$. To convert to a relative velocity $v = c \times \text{ddd} / 100\,000$ where c is the sound velocity (assume 1500m/s if no data is available). Positive values indicate the units are moving apart, i.e. increasing range. If the system timer module is enabled, the optional timestamp will also follow, T, where <t*14> is the absolute system time count at 1MHz. The timestamp is taken at the point the frame synch is detected.

Example

Local Device

```
> $B05Hello
$B05<CR><LF>
```

Remote Device Default

```
#B00705Hello<CR><LF>
```

Remote Device with LQI Enabled

```
#B00705HelloQ56D+000<CR><LF>
```


\$C – Channel Impulse Response

Command

\$C<m><xxx> transmits a ping request to modem <xxx> and process the returned ack to produce a channel impulse response. <m> can be M for magnitude, or C for complex values.

Response

\$C<m><xxx><CR><LF> is returned immediately or **E<CR><LF>** on error. On receipt of the ack **#C<m><xxx>T<ttttt>L<zzzzz><vv*L><CR><LF>** is returned or **#TO<CR><LF>** on timeout. Where the propagation time <ttttt> is a 16 kHz counter. Range = <ttttt> × c × 3.125 × 10⁻⁵ where c is the sound velocity (assume 1500m/s if no data is available). The impulse response values of length <zzzzz> follow, where for Magnitude they are binary uint16 values over two consecutive bytes, and for Complex they are alternating binary int16 values over two consecutive bytes each for Real and Imaginary. Samples for correlation are taken at 16 kHz. For Magnitude mode the results cover the period –6.25 ms to 18.75 ms, whilst the Complex results cover –3.125 ms to 9.375 ms. The cross-correlation results are fully normalised using the received signal energy. To convert the integer units for Magnitude mode divide the uint16 values by 50 000.0 to produce a result between 0.0 and 1.0. For Complex mode divide the int16 value by 25000.0 to produce a result between –1.0 and 1.0.

Example

Local Device

```
> $CM100
$CM100<CR><LF>
#CM100T32000L00400<vvvv...vvvv><CR><LF>
> $CM101
$CM101<CR><LF>
#TO<CR><LF>
```

\$D – Device Unique ID

Command

\$D request the device's unique id.

Response

#DID:0x<a*20>-A8:0x<b*2>-A16:0x<c*4>-A24:0x<d*6>-A32:0x<e*8><CR><NL> where <a*20> is a hex encoded string of the 80-bit unique ID, and the <b...>,<c...>,<d...>,<e...> are hex encoded strings of the 8, 16, 24, and 32-bit CRC values generated from the 80-bit unique ID.

Example

Local Device

```
> $D
#DID:0x00290035401151334E45-A8:0x99-A16:0x760E-A24:0x332545-A32:0xEF9C2B6A
```

\$E – Echo Data

Command

`$E<xxx><yy><data>` transmits a message `<data>` of length `<yy>` to modem `<xxx>`. The remote device will rebroadcast the message `<data>` but will not pass the received data to the UART. This is a test and diagnostic function.

Response

`$E<xxx><yy><CR><LF>` is returned immediately or `E<CR><LF>` on error. If the transmission is successfully received by the remote device a broadcast packet will be transmitted and received by the local device as `#B<xxx><yy><data>[Q<zz>D<+ddd>][T<t*14>]<CR><LF>`. See Broadcast section for parameter details of received broadcast data.

Example

Local Device Default

```
> $E10005Hello
$E10005<CR><LF>
#B10005Hello<CR><LF>
```

Local Device with LQI Enabled

```
> $E10005Hello
$E10005<CR><LF>
#B10005HelloQ65D+000<CR><LF>
```

\$F – Frame Beacon

Command

`$F[T<z*14>]` transmits a frame beacon to all units within range. If the System Timer is enabled, then an optional transmit time can be appended.

Response

`$F<CR><LF>` is returned immediately to confirm the frame beacon will be broadcast or `E<CR><LF>` on error.

Remote Device

`#F<aaa>[T<t*14>]<CR><LF>` is produced at the serial output on the receiving modem.

Where <aaa> is the transmitting address. If the system timer module is enabled, the optional timestamp will also follow, T, where <t*14> is the absolute system time count at 1MHz. The timestamp is taken at the point the frame synch is detected.

Example

Local Device

```
> $F
#F<CR><NL>
```

Remote Device

```
#F007<CR><NL>
```

\$H – Help Message

Command

\$H tells the modem to print the help message.

Response

Full printout of available commands.

Example

Local Device

```
> $H
-----
Modem Console Help
-----
$?          - Query Status - Address, Voltage, Build Version.
$A<xxx>     - Set Address to <xxx>.
$B<xx><data>[T<y*14>] - Broadcast Message <data> of length <xx>.
               Optional:[Transmit at system time count <y*14>].
$C<m><xxx>   - Channel Impulse Response <M>ag/<C>omp from modem <xxx>.
$D          - Device Unique ID.
$E<xxx><yy><data> - Echo Message <data> of length <yy> from modem address <xxx>.
$F[T<z*14>]   - Frame Beacon broadcast.
               Optional:[Transmit at system time count <z*14>].
$H          - Print this Help message.
$M<xxx><yy><data>[T<z*14>] - Unicast & Ack Message <data> of length <yy> to modem <xxx>.
               Optional:[Transmit at system time count <z*14>].
$N          - Noise Measurement over 1 second.
$P<xxx>     - Ping Modem address <xxx>.
$Q          - Corrected Errors in Last Message.
$R          - Reset the modem.
$S          - Spectrum Measurement over 1 second.
$T<xxx>     - Test Message from modem address <xxx>.
$U<xxx><yy><data>[T<z*14>] - Unicast Message <data> of length <yy> to modem <xxx>.
               Optional:[Transmit at system time count <z*14>].
$V<xxx>     - Battery Voltage and Noise from modem <xxx>.
$X          - Extension Messages:
$XF<x>      - Flag RxS also high during transmit <E>nable/<D>isable.
$XQ<x>      - Link Quality Indicator <E>nable/<D>isable.
$XT<x>      - 1MHz System Time <E>nable/<D>isable/<C>lear/<G>et Count.
$Z          - Sleep and Wake On Serial
-----
```

\$M – Unicast Data with Ack

Command

`$M<xxx><yy><data>[T<z*14>]` transmits a message <data> of <yy> bytes to modem <xxx>. Data can be any printable or non-printable byte value. <yy> is the number of transmitted bytes as two ASCII decimal digits (02-64). If the System Timer is enabled, then an optional transmit time can be appended.

Response

`$M<xxx><yy><CR><LF>` is returned immediately or `E<CR><LF>` on error. If the remote device successfully receives the data it will transmit an ack. The local device will then return `#R<xxx>T<ttttt><CR><LF>` or `#TO<CR><LF>` on timeout. Where the propagation time <ttttt> is a 16 kHz counter. Range = <ttttt> × c × 3.125 × 10⁻⁵ where c is the sound velocity (assume 1500m/s if no data is available).

Remote Device

`#U<yy><data>[Q<zz>D<+ddd>][T<t*14>]<CR><LF>` is produced at the serial output on the receiving modem. Where <yy> is the number of bytes <data> received. Additional statistics follow with quality, Q, as a number <zz> from 00-99. Doppler tracking is based on the average sample per symbol change over the whole packet. Fractional-sample per sample, s = ±<ddd>/1000 %. To convert to a relative velocity v = c × <ddd>/100 000 where c is the sound velocity (assume 1500m/s if no data is available). Positive values indicate the units are moving apart, i.e. increasing range. If the Link Quality Indicator is enabled, then the quality statistics will follow. If the system timer module is enabled, the optional timestamp will also follow, T, where <t*14> is the absolute system time count at 1MHz. The timestamp is taken at the point the frame synch is detected.

Example

Local Device

```
> $M10005Hello
$M10005<CR><LF>
#R100T23000<CR><LF>
```

Remote Device Default

```
> $
#U05Hello<CR><LF>
```

Remote Device with LQI Enabled

```
> $
#U05HelloQ56D+000<CR><LF>
```

\$N – Noise Measurement

Command

\$N starts a local noise measurement process, sampling over 1 second.

Response

#NR<xxxxxx>P<yyyyyy>M<zzzzzz><CR><LF> where <xxxxxx> is RMS noise, P is peak-to-peak noise, and M is mean magnitude noise. The noise is sampled at 16 kHz for 1 second. Returned values are ADC units. To convert to a voltage = $\text{adcunits} * 2.5/65536.0$. Receive sensitivity of NM3 is approximately -145 dB re 1 μPa @ 1m. Where noise = $20 \log_{10}(\text{voltage}) + 145.0$ dB

Example

Local Device

```
> $N
#NR000121P001068M000099<CR><LF>
```

\$P – Ping Modem

Command

\$P<xxx> transmits a ping request to modem <xxx>.

Response

\$P<xxx><CR><LF> is returned immediately or **E<CR><LF>** on error. If the remote device successfully receives the request it will transmit an ack. The local device will then return **#R<xxx>T<ttttt><CR><LF>** or **#TO<CR><LF>** on timeout. Where the propagation time <ttttt> is a 16 kHz counter. $\text{Range} = \text{<ttttt>} \times c \times 3.125 \times 10^{-5}$ where c is the sound velocity (assume 1500m/s if no data is available).

Example

Local Device

```
> $P100
$P100<CR><LF>
#R100T32000<CR><LF>
```


\$Q – Get Quality Indicator

Command

\$Q gets a quality indicator for the last received data message.

Response

\$C<n><CR><LF> is returned immediately where <n> is the number of RS symbol errors corrected in the last received message, or '-' if the packet failed to decode.

Example

Local Device

```
> $Q
$C2<CR><LF>
```

\$R – Reset Modem

Command

\$R resets the modem.

Response

\$R<CR><LF> is returned immediately then the modem resets.

Example

Local Device

```
> $R
$R<CR><LF>
```

\$S – Spectrum Measurement

Command

\$S starts a local spectrum measurement process, sampling short blocks and averaging over 2 second.

Response

\$S<CR><LF> is returned immediately then after a second **#S<xxxxx><vvvv . . . vvvv><CR><LF>** is returned where <xxxxx> is the number of positive FFT magnitude bins returned from DC up to and including Nyquist. Each magnitude is binary uint16 in two consecutive bytes. Block lengths of 512 samples at a rate of 160 kHz are captured and FFT is applied with bin magnitudes stored. This process is repeated with a total of 64 blocks over the elapsed duration of 2 seconds.

Example

Local Device

```
> $S
$S<CR><LF>
#S00257<vvvv . . . vvvv><CR><LF>
```

\$T – Test Message

Command

\$T<xxx> sends a test message request to modem <xxx>.

Response

\$T<xxx><CR><LF> is returned immediately or **E<CR><LF>** on error. When the remote device received the request, it will broadcast a test data packet.

Example

Local Device

```
> $T100
$T100<CR><LF>
#B10064Hello! This is a Nanomodem v3 DSSS test
      transmission at 640 bps.<CR><LF>
```

\$U – Unicast Data

Command

`$U<xxx><yy><data>[T<z*14>]` transmits a message <data> of <yy> bytes to modem <xxx>. Data can be any printable or non-printable byte value. <yy> is the number of transmitted bytes as two ASCII decimal digits (02-64). If the System Timer is enabled, then an optional transmit time can be appended.

Response

`$U<xxx><yy><CR><LF>` is returned immediately or `E<CR><LF>` on error.

Remote Device

`#U<yy><data>[Q<zz>D<+ddd>][T<t*14>]<CR><LF>` is produced at the serial output on the receiving modem. Where <yy> is the number of bytes <data> received. If the Link Quality Indicator is enabled then additional statistics follow with quality, Q, as a number <zz> from 00-99. Doppler tracking is based on the average sample per symbol change over the whole packet. Fractional-sample per sample, $s = \pm \text{ddd} / 1000 \%$. To convert to a relative velocity $v = c \times \text{ddd} / 100\,000$ where c is the sound velocity (assume 1500m/s if no data is available). Positive values indicate the units are moving apart, i.e. increasing range. If the system timer module is enabled, the optional timestamp will also follow, T, where <t*14> is the absolute system time count at 1MHz. The timestamp is taken at the point the frame synch is detected.

Example

Local Device

```
> $U10005Hello
$U10005
```

Remote Device Default

```
#U05Hello<CR><LF>
```

Remote Device with LQI Enabled

```
#U05HelloQ56D-001<CR><LF>
```

\$V – Battery Voltage and Noise Measurement

Command

\$V<xxx> sends a voltage and noise measurement request to modem <xxx>.

Response

\$V<xxx><CR><LF> is returned immediately or **E<CR><LF>** on error. When the remote device receives the request it will take a battery voltage measurement, and a noise measurement over 1 second. The data will then be transmitted as a broadcast data packet. When the local device receives this as **#B<xxx><yy>V<vvvvv>R<rrrrrr>P<pppppp>M<mmmmmm>[Q<qq>D<+ddd>]<CR><LF>** where <yy> is the length of the data bytes, <vvvvv> is the battery voltage where volts = <vvvvv> * 15/65536, <rrrrrr> is the RMS noise in adc units, <pppppp> is the peak-to-peak noise in adc units, <mmmmmm> is the mean magnitude in adc units. See Section 1.3.8 for information on converting adc units to noise dB units.

Example

Local Device Default

```
> $V100
$V100<CR><LF>
#B10027V21997R000124P001988M000099<CR><LF>
```

Local Device with LQI Enabled

```
> $V100
$V100<CR><LF>
#B10027V21997R000124P001988M000099Q59D+001<CR><LF>
```

\$W – Wake

Command

\$W tells the modem to wake up and activate the acoustic receiver processes. This command may need to be sent repeatedly as the serial port will take a few milliseconds to start up before it can receive serial bytes correctly.

Response

\$W is returned to confirm that the modem is awake.

Example

Local Device

```
> $W  
> $W  
$W<CR><NL>
```

\$XF – Flag RxS During Transmit

Command

\$XF<x> where <x> is the action. **\$XFE** = Enable RxS high during transmit. **\$XFD** = Disable RxS high during transmit. The RxS Flag by default is only high when the receiver detects a synch chirp. Some applications may need to inform associated electronics when the modem is also transmitting.

Response

#XF<e><CR><LF> where <e> is E (enabled) or D (disabled).

Example

Local Device

```
> $XFE
#XFE<CR><LF>
> $XFD
#XFD<CR><LF>
```


\$XQ – Link Quality Indicator

Command

\$XQ<x> where <x> is the action. **\$XQE** = Enable LQI. **\$XQD** = Disable LQI. When the link quality indicator is enabled, incoming data packets have the statistics appended. The link quality indicator is disabled by default on modem power on. If the Link Quality Indicator is enabled then additional statistics follow as [Q<zz>D<+ddd>] with quality, Q, as a number <zz> from 00-99. Doppler tracking is based on the average sample per symbol change over the whole packet. Fractional-sample per sample, $s = \pm\text{<ddd>/1000 \%}$. To convert to a relative velocity $v = c \times \text{<ddd>/100 000}$ where c is the sound velocity (assume 1500m/s if no data is available). Positive values indicate the units are moving apart, i.e. increasing range.

Response

#XQ<e><CR><LF> where <e> is E (enabled) or D (disabled).

Example

Local Device

```
> $XQE
#XQE<CR><LF>
> $XQD
#XQD<CR><LF>
```

\$XT – System Time

Command

\$XT<x> where <x> is the action. **\$XTE** = Enable system timer. **\$XTD** = Disable system timer. **\$XTC** = Clear system timer count. **\$XTG** = Get system timer count. When the system timer is enabled, incoming data packets have the timestamp appended using this system timer. The system timer is disabled by default on modem power on.

Response

#XT<e><z*14><CR><LF> where <e> is E (enabled) or D (disabled) and <z*14> is the current ascii decimal counter value of the 1MHz system timer.

Example

Local Device

```
> $XTG
#XTD0000000000000000<CR><LF>
> $XTE
#XTE0000000000000000<CR><LF>
> $XTG
#XTE000000004127977<CR><LF>
> $XTG
#XTE000000006527930<CR><LF>
> $XTC
#XTE0000000000000000<CR><LF>
> $XTG
#XTE000000002415802<CR><LF>
> $XTD
#XTD0000000000000000<CR><LF>
> $XTG
#XTD0000000000000000<CR><LF>
```

\$Z – Sleep

Command

\$Z disables the acoustic receiver and puts the modem into a low power sleep mode. The modem stays in this state until it receives a user command **\$W** to wake it up again.

If the system timer is enabled, the counter will pause while the unit is asleep.

Response

\$Z<CR><NL> is returned immediately to confirm the modem is entering sleep state.

Example

Local Device

```
> $Z
$Z<CR><NL>
```