

# SAM-1 Technical Reference Manual

## Miniature Acoustic Modem

### *Technical Reference Manual*



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## 1. Introduction

The SAM-1 is a miniature acoustic modem. It will transmit and receive digital data between underwater stations up to a typical range of 250 meters, with up to 1000 meters possible under ideal (quiet, deep-water) conditions. The SAM-1 modem is designed for reliable exchange of data in a variety of underwater environments, from shallow areas or harbors all the way to deep oceanic waters.

The following list summarizes the SAM-1 features.

### SAM-1 Features

- Acoustic data exchange in shallow, confined and deep waters alike.
- Works in high multi-path and noisy environments.
- Robust data exchange format, including checksum.
- Small size and low cost.
- Low standby power consumption and energy efficient data transmission.
- 250 meters typical range.
- Instant operation (no configuration) for use with “dumb devices.”
- Configuration through serial commands for use with “smart devices.”
- Very simple to use.

The SAM-1 is a simple, effective and low-cost solution for a variety of applications that demand reliable data exchange at slow to medium speeds. Here are a few examples.

### A few Applications for the SAM-1

- Retrieval of data from underwater instruments
- Control of underwater instruments and equipment
- Control of autonomous underwater vehicles (AUV).
- An 'acoustic teletype' for communication with submarines or among submarines.
- Cost saving replacement of wired data links.
- Marine mammal telemetry.
- Acoustic diver or vehicle identification.
- Remote control of lift bags.
- Acoustic releases.
- Communication with stealthy instruments that are buried into the sea floor.

## 2. Unpacking

Please ensure that your shipment does contain these components.

- 1 ea. SAM-1 module
- 1 ea. PIG5-D 5' underwater modem cable terminated with a LINK-D compatible AMP connector
- This manual

### **SAM-1 Component List**

If a shipment is incomplete, please immediately contact Desert Star Systems. If you are missing any components required for system operation, obtain these components before proceeding.

## **3. Modem Installation**

The SAM-1 is always used in conjunction with a 'host device', i.e. an instrument, vehicle, computer or other data receiving or transmitting device. Because the SAM-1 does not have an internal battery, it must be powered by an external source.

Installation of the SAM-1 is a matter of selecting a proper place for the modem and linking it to the host device and a power source.

The sonar transducer is mounted on one end of the housing. The utility connector and a status LED occupy the other end.

The sonar transducer is the antenna of the SAM-1. Mount it so that it will not be shadowed by any obstacle. The direct path between the transducers on both ends of the acoustic data link must be free of obstructions. Use a cable clamp, a bracket, or any other suitable means to secure the SAM-1 to the host device.

The SAM-1 features a 5-pin underwater connector through which it communicates with the host and receives power. The connectors on the SAM-1 are models MCIL5F, from Seacon. This is shipped with a short cable (part # PIG5-D) that is terminated with a MCIL5M connector on one end. The other end is terminated with a 9-pin AMP connector, through which it can be linked to the LINK-D data exchange cable, which is also included.

### **3.1 Electrical Installation For Modem Test**

To test the SAM-1, it is convenient to connect each modem to a PC or a terminal. A two-way 'acoustic teletype' system is thus created. Follow these instructions.

- Join the underwater cable and the data exchange cable. Connect the ends of the assembly to the modem and a personal computer or terminal respectively.
- Power the modem by applying a +8V to +16V source capable of supplying at least 2 ampere to PIN 4 of the AMP connector. Connect the associated negative lead of the power supply to PIN 1 of the AMP connector.

- The modem will be active as soon as power is applied. The LED should flash once per second.

### 3.2 Electrical Installation For Underwater Use

The SAM-1 is normally connected to an underwater host device. For this purpose, an underwater cable is shipped with the modem. The cable is terminated on one end with a 5-pin connector, which plugs into the utility connector of the SAM-1.

The other end of the cable is terminated with a AMP connector which is compatible with the corresponding connector on the data exchange cable (see section 3.1.). This setup is appropriate for test purposes only. For underwater use, remove the AMP connector from the underwater cable and terminate the cable instead with an underwater connector that will link the SAM-1 to your host device.

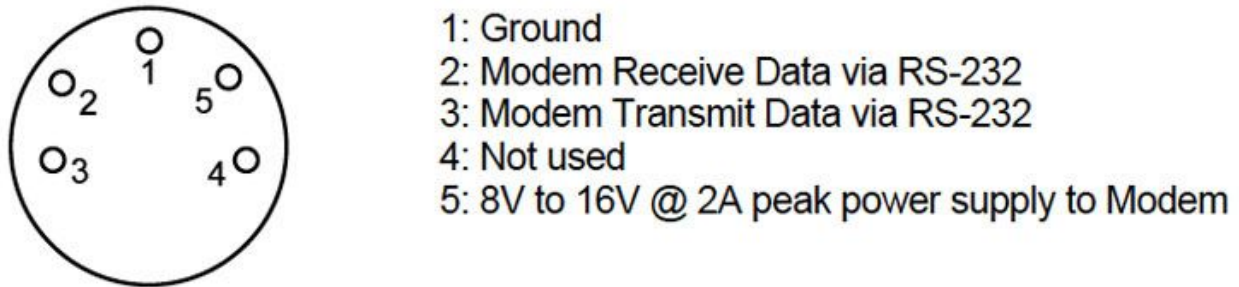


Figure 1: Pin Assignment of the SAM-1 Utility Connector

Figure 2 shows the pin assignment of the SAM-1 utility connector. The signals are explained in detail in figure 3.

Pin #	Signal	Description
1	Ground	The ground return line.
2	Receive Data	The modem data receive line. The modem expects data at 4800 baud, 8 data bits, no parity, one stop bit. Acoustic modems are set to use RS-232 level, default.
3	Transmit Data	The modem data receive line. The modem transmits data at 4800 baud, 8 data bits, no parity, one stop bit. The default is RS-232 levels.

4	Not used	
5	Modem Power	Apply +8V to +16V power for the modem here. Connect the negative lead of the power supply to pin 1. The power supply should be able to supply peak currents of up to 2 Ampere. Do not exceed 16 Volt. This will damage the modem.

Figure 2: SAM-1 Signal Utility Connector Description

### Modem Data

Note that the SAM-1 uses RS-232 levels by default.

The modem requires +8V to +16V power. Receive current is only 21 mA, but in transmit mode the current can reach 2 Ampere. Make sure the battery or power supply has a sufficient maximum current capability.

The modem transmit power varies with the supply voltage. Transmit power is about 183 dB at 8V, rising to about 189 dB at 16V.

**CAUTION!** Do not exceed +16 Volt supply voltage. Higher voltages may damage the modem.

### Modem ON/OFF Switch

The SAM-1 modem is switched on whenever +8V to +16V power is applied at pin 5 of the modem connector. The LED will flash when the modem is on.

## 4. Modem Activation

The SAM-1 modem is active whenever power is applied to the Modem itself. When the Modem is connected to a power source it is automatically powered on; thus, when power is removed it is off.

The status LED shows what the modem is doing.

Blink Pattern	Meaning
LED off	SAM-1 is off.

One brief blink, once per second	SAM-1 is standing by and waiting for data or transmitting data.
Fast double blink	The station has received a sonar data. This is the pattern you should see once the station is deployed (in the water) and receiving sonar signals.
Continuos rapid blinking.	The supply voltage is less than about 9 Volt.

Figure 4: Status LED Blink Patterns

## Modem Configuration

The modem is factory configured for these settings:

<b>Serial Data Port:</b>	4800 baud, 8 data bits, no parity, one stop bit, (Xon/Xoff software handshaking)
<b>Serial Data Port Levels:</b>	RS-232
<b>Acoustic Data Receive Speed:</b>	Speed 5 (13 bit/sec, single channel)
<b>Acoustic Data Transmit Speed:</b>	Speed 5 (13 bit/sec, single channel)
<b>Receiver Sensitivity:</b>	'High' (detection threshold 16 units)

Figure 5: Factory Configuration of the SAM-1

These parameters can be changed during operation in the command mode of the modem, see section 6.3. for details. Changing the parameters by sending serial commands is preferred over changing the switch settings, because this does not require opening the modem. If you do need to open the SAM-1, please contact Desert Star Systems for instructions.

## 6. Modem Operation

The SAM-1 operates as a simple acoustic modem:

- Any data received via the serial data interface is transmitted via sonar.
- Any data received via sonar is transmitted via the serial data interface.

Two SAM-1's will implement a two-way acoustic data link.

After power-up, the modem sends an identifier string through the serial data port. The data string identifies the software version and the mode of operation.

The modem is ready for operation immediately after the transmission of this string. The following sections explain modem operation.

The SAM-1 uses Xon/Xoff software handshaking to insure that the host does not transmit data to the SAM-1 faster than it can be received. The SAM-1 will send the X-off character when less than 8 bytes remain available in its 32-byte serial data receive buffer. The SAM-1 internally buffers data received from the host. It will send the X-on character as soon as at least 8 bytes of space is available.

The host must have Xon/Xoff turned on because with Xon/Xoff not turned on, failure to stop sending data will result in the loss of that data. Any data sent from the hosts beyond the buffer limitations (32bytes) will not be received until after the receiving unit has completely emptied its buffer.

## **6.1 Serial Port Data Format**

### Serial Data Format

The serial data interface operates at 4800 baud, 8 data bits, no parity bit, 1 stop bit, Flow Control: Xon Xoff (software handshaking). The 4800 baud speed is fast enough to keep up with the fastest sonar data transmission yet slow enough to be supported by just about any device.

### Serial Data Levels

The serial data interface uses RS-232 levels in order to keep power consumption to a minimum.

## **6.2 Acoustic Data Format**

The modem transmits and receives acoustic data words consisting of one synchronization ping, four data pings and one checksum ping. Each data ping is position coded and represents 4 bits of information, for a total of 16 bits. The checksum is used by the receiver to verify the integrity of each word. The modem's ability to communicate 20 bits worth of information with just six pings makes it a very energy efficient transmitter.

Like most modems, the SAM-1 receives and transmits 8-bit data words via its serial data interface. During transmit, it will pack two 8-bit serial data words into a 16-bit acoustic data word which is transmitted. No data is transmitted until at least two bytes have been received via the serial data interface. To ensure that the last byte of your data sentences is transmitted, append an idle character (NULL, SPACE, etc.) to each data sentence.

Each received data word is unpacked into two 8-bit words, which are transmitted via the serial data interface.

If the SAM-1 detects a bad checksum on an incoming acoustic data word, it will transmit '###' via the serial data link. This bad data indicator is useful to guide the adjustment adjust modem sensitivity and speed.

### Acoustic Transmit/Receive Switching

The SAM-1 implements a half-duplex acoustic modem. Data is either transmitted or received at any one time. Data can not be received and transmitted via the acoustic link at the same time. By default, the modem is in receive mode. It switches automatically to transmit mode as soon as at least two data bytes are in its serial input data buffer. The modem will remain in transmit mode until less than two bytes remain in its serial input data buffer. It is up to you, the user, to coordinate data transmission and reception. **If the modems at both end of an acoustic link transmit data at the same time, all data will be lost.**

The SAM-1 can be used to exchange data in multi-station networks. The data transmitted by any station will be received by all other stations. It is up to the user to coordinate transmissions in such networks.

## 6.3 Modem Control

The modem has a data mode and a control mode.

- **Data Mode** is used to transmit and receive data.
- **Control Mode** is available to change modem operation parameters.

The modem will be in data mode after power up. To switch to control mode send '###'. The modem will acknowledge control mode by sending '<CM>'. To return to data mode, send 'D'. The modem will acknowledge data mode by sending '<DM>'. The table below lists the modem control commands.

Command	Function
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###	Switch to control mode. The modem transmits '<CM>' to indicate control mode. <b>This command is available in data mode only. All other commands are available in control mode only.</b>
D	Return to data mode. The modem transmits '<DM>' to indicate data mode.
Sx	Set the acoustic transmit data speed, telemetry speed (see section 6.4. for details): S0: 9 (15) bit/sec, frequency hopping
	S1: 24 (38) bit/sec, frequency hopping
	S2: 48 (77) bit/sec, frequency hopping
	S3: 96 (154) bit/sec, frequency channel
	S4: 3 (5) bit/sec, single-channel
	S5: 8 (13) bit/sec, single-channel
	S6: 23 (38) bit/sec, single channel
	<p><b>Note: Use speeds S4 through S6 only for communication between two SAM-1 modules. Use speeds S0 through S3 when communicating with another frequency hopping capable receiver.</b></p>
Rx	Set the acoustic receive data speed (see section 6.4. for details):
	R4: 3 (5) bit/sec, single-channel
	R5: 8 (13) bit/sec, single-channel
	R6: 23 (38) bit/sec, single channel

<b>Txx</b>	Set the receiver detection threshold. The minimum possible threshold is T01. The modem is at its maximum sensitivity of 85 dB. The maximum threshold is T99, equivalent to a sensitivity of about 125 dB.
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Notes:

1. Data speeds are user data throughput. The raw bit transmission speed is given in parenthesis.

Figure 6: Modem Control Commands

## 6.4 How To Set Modem Speed And Sensitivity

### Modem Receiver Sensitivity

The sensitivity of the receiver modem is adjusted by setting the detection threshold. A low detection threshold makes the modem very sensitive. This increases the maximum data exchange range, but at the same time makes the modem more susceptible to noise. A high detection threshold means greater immunity to noise but a shorter transmit range. In theory, a doubling of the threshold setting will cut the maximum range in half. In reality this effect may be more or less pronounced, depending on the acoustic environment.

The following table gives a rough guide of recommended settings for various environments.

Environment	Threshold Range	Comment
Lakes	4 - 12	Lakes tend to be very quiet waters due to lack of biological activity. Use a high sensitivity unless boat traffic calls for a reduced sensitivity.
Pools & Tanks	8 - 99	Pools and tanks are often quiet, though they will at times pick up noise from nearby machinery. However, the small size of most pools and tanks normally does not require a high sensitivity, and better reliability may be achieved by reducing the sensitivity. The very strong and persistent echoes found in pools may also require a reduced sensitivity. On the other hand, pools and tanks tend to 'smear' the leading edge of sonar pulses. Especially when attempting to user higher data exchange speeds, you may have to reduce the detection threshold to fight this effect. In

		general, experimentation is called for to adjust a system for a given pool or tank.
Shallow Reefs	16 - 50	Shallow reefs, both in tropical and temperate seas often harbor a lot of biological noise making activity. The noise of the snapping shrimp for example is extremely common - a crackling noise well known by most divers. We sometimes operate at settings of as little as 12 here, but we have also seen noise as high as 48 units.
Deep Water	4 - 12	Deep oceanic waters tend to be quiet in the frequency range. Your modem can probably be rather sensitive and cover very long distances.
Harbors	8 - 99	There can be much man induced noise in harbors, but at other times harbors a quiet. Do some experimentation.
Hydraulic Equip.	30 - 99+	Hydraulic equipment, including hydraulic ROV are very noisy. Hydraulics create a 'whine' that extends from a few hertz all the way to 100 kHz and beyond. Consequently, sensitivity must be reduced. In fact, it is quite possible that a sensitivity beyond the maximum of 99 is required (we have operated as high as a 270 unit equivalent). In this case, contact Desert Star Systems to modify your Modem for reduced sensitivity.

**Figure 7: Modem Sensitivity Selection Guide**

In general, finding the proper threshold setting to obtain the required range yet not be affected by ambient noise will require some experimentation. After the useable range is found, you may set the sensitivity 'permanently' or your software may implement a mechanism that controls the sensitivity to track changing noise levels.

One good method to experiment is to connect the SAM-1 modules to a PC running a terminal emulation program. HyperTerm/Tera Term are such applications that are available with Microsoft Windows enabled PC. Deploy the SAM-1 modules at the designated site. Then, follow this procedure:

- Use one SAM-1 to listen. Reduce the detection threshold until you see '###' symbols appearing on the screen. These bad data symbols indicate that the SAM-1 is picking up noise (the other SAM-1 is not transmitting!). Now, increase the detection threshold until the '###' symbols no longer appear. You have found the minimum useful detection

threshold. Be careful, however: If the detection threshold is way too low, you may not see any '##' symbols because the noise is constantly beyond the detection threshold.

- Now, start typing on the terminal that is connected to the second SAM-1. Whatever you type should appear on the screen of the receiving SAM-1. If that is not the case, you may be out of range or the data exchange speed may be too high (in pools and other environments with long echoes). Once a data path is established, increase the receiver detection threshold until the data either becomes erroneous ('##' symbols) or no data is received at all. You have now found the maximum limit of the useful detection threshold range for this environment.

Be also aware that the SAM-1 mounting location can strongly affect signal strength and thus the maximum possible operating range. For greatest range, keep the data path free of obstructions and stay at least six feet away from the water surface, the sea floor or the walls of pools and tanks.

### Acoustic Data Telemetry Speed

Communication between acoustic modems requires that all modems use the same telemetry speed (S0- S6). Because the SAM-1 receiver is a single channel design, you must use the single channel mode (speeds S4, S5 and S6) when communicating among SAM-1 modules. The frequency hopping channels are available only when an SAM-1 talks to another frequency hopping capable receiver.

High data exchange speeds are desirable because data is exchanged faster, but the data transfer at higher speeds is also less reliable. The limiting factor is normally the duration of the echoes in the operating environment. The longer the echo lasts, the longer the modem has to wait before it can use a transmit frequency again. Thus, pools require very slow data speeds, while data exchange can be much faster in wide-open waters. In general, the chosen data exchange speed should not exceed the minimum requirement of your application as this will unnecessarily reduce data exchange reliability.

The following table is a guideline to speed selection for some typical environments.

<b>Environment</b>	<b>Maximum Speed</b>	<b>Comment</b>
Lakes	Single Channel: S5-S6  Freq. Hopping: S2-S3	A 'typical lake', i.e. a muddy, gently sloping depression in the ground will have few echo surfaces. Echoes will not last long and thus higher speeds can be used.

Pools & Tanks	Single Channel: S4  Freq. Hopping: S0	Pools and tanks exhibit very persistent echoes. Only minimum operating speeds are possible.
Shallow Reefs	Single Channel: S5  Freq. Hopping: S1-S2	
Deep Water	Single Channel: S6  Freq. Hopping: S2-S3	There are few echoes in deep waters, so higher speeds are possible.
Harbors	Single Channel: S4-S5  Freq. Hopping: S0-S2	The smooth, hard surfaces of ships and docks efficiently reflect sonar signals. Echoes are of moderate to strong persistence.

Figure 8: Modem Speed Selection Guide

To test for the maximum possible speed, establish a link between two modems. Start operating at a slow speed, then increase the speed until data exchange becomes unreliable. You may be able to operate at a somewhat higher speed if you reduce the modem sensitivity. However, because echo strength can vary greatly from ping to ping, trying to squeeze the last bit of speed by this means may result in a data link with varying reliability.

## 7. Modem Maintenance

Your model SAM-1 requires very little maintenance. Just follow these pointers.

- Apply a thin film of silicone grease to the cable connector before mating it to the bulkhead connector.
- Never dive the SAM-1 with an open utility connector. If the modem is not connected to a cable, use a dummy plug (not included, available separately).
- Rinse the SAM-1 in fresh water after use.

## **Appendix: A**

The Appendix: A will reference testing that was conducted in Moss Landing, California at the boat docks. Data, 200 Character text strings, was successfully transmitted and received up to 635 feet and as little as 10 feet. The water depth was 15 feet, on average.

### **Threshold:**

When used in noisy environments, such as harbors, we received the best transmission using a higher threshold number, such as T60-99. When a boat was passing nearby or an engine was running a few feet away, your text that you receive will become impaired. You will not see what is being sent; rather you receive a pair of #'s. We discovered that the lowest threshold that yields reliable data is anything above T32; when using a low threshold, T8, the receiving unit only receives a partial message. In our testing at 155 Feet, at T16 and below we received the first ¼ of the message and the rest was lost.

### **Telemetry Speed:**

We tested in a range from 10-845 Feet in order to find the limits of the transmission of the SAM-1s (in a harbor). When deciding on the telemetry speed channel to use, we recommend that you test all three before deciding on which to use. S4 is the slowest available, 3 bit/second; however, in our testing it was not much more reliable than the faster speeds. S5 is the medium telemetry speed channel, 8 bits/second, and it did not yield a significant benefit over S6. S6 being the fastest at 23 bits/second was quite reliable as long as you set the threshold at a higher number, T85-T99. In our Harbor Testing, we did not notice a significant difference between the telemetry speeds, S4-S6; however, when operating in other locations results may vary.

When you go just beyond the maximum range of the units you will no longer receive data. You will not receive errors ##'s; you will not receive anything. The character rate error in these tests was 3% and the bit rate error was .15%.



Figure 9: Short Range Testing

In Figures 9 and 10, we were to verifying that the SAM's would have the ability to transmit data in short and long ranges. We tested from 10-845 feet on all the telemetry speed channels and at a variety of thresholds. From 815 Feet and beyond, the data was no longer received. The results remained equal regardless of separation.



Figure 10: Long Range Testing

## 8. SAM-1 Specifications

Size:	135 mm L x 40 mm D (5.3" L x 1.6" D)
Weight:	230g in air and 50g in water



<b>Depth Rating:</b>	300 meters max. working depth
<b>Operating temperature:</b>	0-70 degrees Celsius
<b>Data I/O:</b>	RS-232 serial data link
<b>Status Indicator:</b>	Status LED
<b>Serial Buffer:</b>	The size of the serial buffer is 32 bytes
<b>Sonar transceiver:</b>	TX power 183 dB @ 8V - 189 dB @ 16V
	4-channel frequency hopping transmitter, 33.8 kHz- 42 kHz standard, 65 kHz - 75 kHz optional
	RX sensitivity $\leq$ 95 dB re. 1 $\mu$ Pa
	4th order continuous time bandpass filter
	Single channel receiver, 33.8 kHz
<b>Sonar transducers:</b>	33 kHz - 42 kHz omni-directional transducer standard
<b>Sonar range:</b>	100 - 1000 meters communication range, depending on sea conditions
<b>Sonar modulation:</b>	Single channel receiver, pulse position modulated
	For detailed information please see section 4.7 in FAQ linked below:
	<a href="#">link</a>
<b>Sonar bitrate:</b>	3-23 bits/sec actual user data (5 - 35 bits/sec raw) receive

	3-96 bits/sec actual user data (5 - 150 bits/sec raw) transmit
<b>Sonar data format:</b>	16-bit data + 4 bit checksum per word
<b>Sonar Navigation:</b>	Compatible with Desert Star Systems tracking systems
	Navigation range is 100-1000 meters, depending on sea conditions.
	Distance measurements repeatability +/- 0.15 m
<b>Power consumption:</b>	8V to 16V supply voltage
	21 mA in sonar receive mode
	Up to 2 Ampere peak in high-power sonar transmit mode
<b>Data transmit power:</b>	30 mAh per 1000 user data bytes with 16V supply voltage (189 dB transmit power)
	15 mAh per 1000 user data bytes with 8V supply voltage (183 dB transmit power)

**Note: all specifications are subject to change without notice**