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**TM8000** mobile radios

TN-855-AN  
TM8000  
Internal Modem



Application Note  
5 April 2004

This application note provides an introduction to the data facilities that Tait provides with the TM8000 series of mobiles. It covers the internal software modems provided with the TM8000 range and the protocols used to drive them.

This application note is intended for System Integrators.

## 1 Overview

As a standard feature, the TM8105 and TM8115 mobiles come with an internal DSP (Digital Signal Processor) 1200-baud modem.

As an option, the radio can be upgraded to provide a high-speed 12000bps or 19200bps modem. This high-speed option is known as THSD (Tait high-speed data).

The 19200bps (19k2bps) option can only be used on wideband channels (25kHz) and is not available in some countries due to type approval restrictions.

These modems have a number of configurable parameters, which are configured using the TM8000 radio programming software.

The 1200 baud standard option uses the rugged FFSK (Fast Frequency Shift Keying) modulation scheme; this works well at low signal levels and through most repeaters.

The THSD option uses a 4 level frequency shift keying modulation scheme, which occupies most of the available audio bandwidth and requires synchronisation.

There are a number of features that have been added to the THSD option to make it as rugged as possible. However, as with most high-speed data modems, it will not work as well as FFSK at lower signal levels and may not successfully pass through many repeater systems.

The choice of modem ultimately comes down to the amount of data to be transferred and the RF path between the radios.

## 2 Protocols

Two modes are used in conjunction with the modems; command mode and transparent mode.

### Command Mode

In this mode, a Tait Proprietary protocol, CCDI (Computer Controlled Data Interface), can be used to change channels, send SDMs (short data messages), and various other functions.

A CCDI protocol manual is available which gives a full list of commands.

The format of the commands is in ASCII text: a one letter identifier, eg “s” for send SDM; the number of characters to follow, eg “13”; the data; and finally a two digit checksum.

Command mode allows for a CCDI command to change to transparent mode.

### Transparent Mode

In transparent mode, any data sent to the serial port will be picked up, processed, and sent over the air. At the receiving radio the data will be demodulated, processed, and then sent to the serial port.

This provides a simple interface to an end user; any data sent to the serial port of the radio will appear at the other end, and no special commands are needed to “drive” the modem.

From transparent mode, an escape sequence (if enabled) can be used to change back into command mode.

Transparent mode can use either 1200 baud FFSK or the optional THSD modem.

## 3 DTE Baud Rates

Different baud rates can be used between the DTE and the radio modem; from 1200 to 28800bps.

However, over-the-air data is always transmitted at 1200bps for the FFSK modem, and at 12kbps or 19k2bps for the THSD modem.

If the baud rate is programmed higher than the over-the-air rate, then flow control should be used to prevent buffer over-run.

## 4 Flow Control

The TM8000 provides two forms of flow control:

- Hardware RTS/CTS
- Software Xon / Xoff.

These are configurable in the programming software.

The hardware flow control lines are assigned to programmable I/O pins. Levels for these pins are 3v3 CMOS.

If using the microphone socket, only one GPIO is available, so only RTS or CTS software flow control can be assigned; Xon/Xoff software flow control may be more suitable.

## 5 Buffer

The radio provides a 128-byte receive and transmit buffer for both the THSD and FFSK modems.

## 6 Error Checking and Correction

The 1200-baud FFSK modem does not provide any form of error checking or correction. This is left up to the third party application.

Often error checking or correction is not necessary using FFSK, as this will work well at low signal levels without the FEC enabled.

The THSD modem provides an FEC (Forward Error Correction) option. This uses a Reed-Solomon algorithm and enables the modem to work at lower signal levels.

It is important to note that the effective throughput of the modem will drop when FEC is added. This is due to the information added to the data packet to detect and correct errors.

## 7 Retries

Neither modem will perform retries of missed or incorrect packets; this is instead left up to the third party application.

## 8 Entering and Exiting Data Transfer Mode

Either command or transparent mode can be enabled upon start-up. When the radio is powered on, it can automatically start accepting CCDI commands or start transferring data in transparent mode.

Transparent mode can be entered via a CCDI command from command mode, also, an external GPIO line can be assigned to switch the radio in and out of THSD mode from command mode.

When in THSD mode, other audible (Selcall, DTMF, FFSK, etc) or sub-audible (CTCSS, DCS) signalling schemes are disabled, as the modem requires the full audio bandwidth.

If the radio is required for voice and data communications, the external modem should change the radio into THSD mode (using a CCDI command or an input line) when it has data to send, and then change the radio back to command mode when it has finished sending data.

To activate the modem the following CCDI commands can be used:

- “t02+0CF” - Enter 1200 baud FFSK transparent mode, using “+” as an escape sequence.
- “t02+HB7” - Enter THSD transparent mode (setting as programmed into the radio), using “+” as an escape sequence.

If the radio accepts the command it will issue a prompt (‘.’), otherwise a CCDI error message is returned.

To return to command mode from transparent mode, the escape sequence is used (in the above examples this is the character “+”).

If the radio has been programmed to start up in transparent mode, the default escape character is “+”.

To send the escape sequence, three escape sequence characters are sent in a row (eg “+++”), and then a period of no serial communications for 2 seconds must be maintained.

The radio will then change to command mode.

It is important that the escape sequence does not appear in the user data, sending the modem back to command mode.

It is possible to program the radio to ignore the escape sequence.

## 9 Serial Ports and Physical Connections

The TM8000 range supports three high-speed serial ports. One at the front of the radio, one in the internal options connector, and one at the rear of the radio.

One of these serial ports at a time can be assigned to accept CCDI commands or to transfer data.

These serial ports are at 3v3 CMOS levels.

The front serial port is the microphone socket on the TM8115. This can be converted to RS232 levels by using the T2000-A19 programming lead and the TMAA20-04 RJ12 to RJ45 adaptor.

If using a TM8105 blank control head radio, then the front serial connection is available as a 9-way D-range. The Rx and Tx data levels are 3v3 CMOS.

The internal options connector also provides a serial port at 3v3 CMOS levels; this is available as an 18-way micromatch connector. This is typically used to connect to internally mounted options boards.

The third serial port is available at the rear of the radio; this is a low-density 15-way connector. Levels are also 3v3 CMOS levels.

The radio programming software is used to configure the serial ports, baud rates, and flow control.

## 10 Modulation Schemes

The modulation scheme for the 1200-baud modem is FFSK. Data is represented by 1 cycle of 1200 Hz (logic 1) or 1.5 cycles of 1800 Hz (logic 0), and is transmitted at rates of 1200 bps.

It is important to note that while the FFSK format is widely used, it is unlikely that a third party FFSK modem will be compatible with the Tait 1200 Baud FFSK implementation.

This is mainly due to the proprietary way in which the data is packed and sent over the air.

The THSD modem uses a CP-4GFSK modulation scheme.

This modulation scheme is outlined in the ETSI DIIS specification.

This modulation scheme was chosen mainly for its ability to achieve high data rates while maintaining compliance with ETS300-113, the European data standard.<sup>12</sup>

# 11 Over-air Packing and Processing

How the data is packed and sent over the air is often irrelevant to the end user, as the radio takes care of the packing and formatting so that the external controlling equipment does not have to present its data in any special format.

A brief description of over-air packing and processing is given here for interest.

## 1200 baud Modem

The 1200-baud modem sends data over the air in the following format:

Lead in delay (programmable)	Data block	nth data block	Lead out delay (programmable)
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A data block consists of:

Preamble	Sync	Length	Data	Dummy CRC
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## THSD Modem

The THSD modem sends data over the air in the following format:

Lead in delay (programmable)	30 symbol start sequence	588 symbols data	30 symbol start sequence	. . . . .	588 symbols data	30 symbol start sequence	Lead out delay (programmable)
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## Transmission of Start and Stop Bits

Data presented to the DCE should be no parity, eight data bits, one start bit and one stop bit.

The start and stop bits will be stripped from the data before being sent over the air and re-inserted at the receiving radio.

## Scrambling

In The THSD implementation, data is scrambled before it is packed and sent over the air. This is to prevent the occurrence of long periods of 1's or 0's in the data, which have the potential for a DC offset to occur, possibly causing the data transmission to fail.

## Synchronisation

Synchronisation (sync) sequences are added into the data stream. The sync sequence that occurs every 588 symbols is the same as the start sync sequence.

Synchronisation allows the receiving radio to synchronise its symbol clock with the incoming data. This reduces the possibility of data errors when the transmitting and receiving radios are not exactly on the same frequency due to frequency drift or ageing.

The sync sequence is inverted if the modem is in FEC mode; this tells the receiving radio to expect data packets with FEC data added.

## 12 Layer Two Protocol (THSD)

A simplified layer two protocol is available as a programmable option.

If layer two is not enabled, then the THSD modem will send data in 147-byte 588 symbol blocks.

If there is not enough user data to fill 147 bytes, then the remaining bytes will be padded with a “\”.

The padding characters will be sent out the serial port, with the user data.

Enabling layer two provides a simple Start-Of-Text/End-Of-Text type protocol.

Data is packed and transmitted as it is available in the radio, no padding occurs.

The radio sending the data will stop transmitting as soon as the end of text is detected.

With layer two enabled, baud rates to the DCE can be lower than the over-air data rate.

Layer two is useful in situations where the controlling equipment is expecting the original data sent from the transmitting equipment, and no extra characters.

Layer two is also useful in situations where less than 147 bytes are sent and timing is critical. As the radio will stop transmitting when the end of text is detected, it will take less time to send a smaller data packet (see [“Throughput” on page 9](#)).



## 13 Throughput

The following table shows an approximate indication of throughput for the THSD and FFSK modems, at specific user data values (20 bytes and 80 bytes).

This is intended to give the user an approximate measure to go by. As can be seen from the table, the more data sent, the greater the effective throughput will be.

The numbers in the table show that, when FEC is enabled, the effective throughput will be reduced for the same amount of user data.

Test	LID (ms)	FEC	A	B	C	D	E	F	Tx Time	Lag	bps (system)	bps (OTA)
1200bps	20	N/A	20	166.2	136	429	334.4	503	293	342.7	318.0914513	546.0750853
12kbps	20	No	20	10.3	11.0	69.3	64.9	75.3	58.3	73.2	2124.8	2744.4
1200bps	20	N/A	80	665.4	135.8	989	334.4	1109.4	853.2	342.7	576.8884081	750.1172058
12kbps	10	No	80	41.5	10.5	102.4	61.7	113	91.9	70	5663.716814	6964.091404
12kbps	10	Yes	80	41.4	10.6	159	54.8	158.7	148.4	63.1	4032.766226	4312.668464

<b>LID</b>	Lead in delay (lead out delay set to 0)
<b>FEC</b>	Forward error correction (applicable to THSD modem only)
<b>A</b>	Number of characters sent to the transmitter
<b>B</b>	Time that the last bit of data was received by the transmitter
<b>C</b>	Time transmitter keyed up
<b>D</b>	Time transmitter keyed down
<b>E</b>	Time that first bit of data was output from the receiver's serial port
<b>F</b>	Time that last bit of data was output from the receiver's serial port
<b>Tx Time</b>	Is the time from Tx key up to Tx key down
<b>Lag</b>	Is the time from the start of the first bit being sent to the radio to the first byte being output from the receiver's serial port
<b>bps (system)</b>	Is the effective bits per second (bps) from the first bit being sent to the last bit being received
<b>bps (OTA)</b>	Is the effective bits per second (bps) over the air from key up to key down

**Note** DTE to DCE baud rate was 1200 baud for 1200bps test and 19k2bps for the 12kbps test.

## 14 BER (Bit Error Rate)

The following table gives a comparison of Bit error rates in four different situations; the 1200 baud FFSK modem on a wide and narrow channel spacing, and the high speed data modem (THSD) with and without error correction (FEC).

The BERs were measured according to the approval specification of Maximum Usable Sensitivity. This is the RF signal level at which the modems achieve a BER of  $1 \times 10^{-2}$ .

It can be seen that the FFSK modem produces a more satisfactory BER than the high speed modem and that the BER for the high speed modem is improved using FEC.

Modem	Sensitivity
1200bps FFSK modem, Wide Band	-122.0dBm
1200bps FFSK modem, Narrow Band	-122.6dBm
Narrow Band THSD no FEC	-115.7dBm
Narrow Band THSD with FEC	-118.1dBm

These measurements were performed on radio that has an Rx sensitivity of -121.99dBm for 12dB SINAD.

Sometimes a specification of sensitivity for a BER of  $1 \times 10^{-6}$  is quoted.

For the same radio above, a BER of  $1 \times 10^{-6}$  was measured at -110dBm with the THSD modem with FEC.

## 15 Publication Information

### Compliance Issues

None

### CSO Instruction

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### Issuing Authority

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