SATRE

Satellite Time Transfer and Ranging Equipment

Part No's: 10140 (1 Channel), 10139 (2 Channels), 10221 (3 Channels)

The Photo shows a 2 channel SATRE.

Key features:

• Automated measurements
• Features unmanned, 24 hours / 7 days operation
• Complete remote control over TCP/IP
• Internal measurement database for three months on a 1 minute basis
• Sub-nanosecond TWSTFT with real time results
• Sub-nanosecond TimeSync
• 1, 2 or 3 Receiver Channels (For 3 Receiver Channels, Contact Factory)
The Main applications of the SATRE are:

1. Precise satellite ranging and orbit determination for Geo-Stationary Satellites
2. Precise monitoring and comparison of distant clocks including via intercontinental links
3. Time transfer and synchronisation of remote clocks to a central master clock

Uncertainty of 1 nsec with precision of 30 psec is well within the capabilities of the system. These values are obtained within the first minutes of operation.

The SATRE operations are compatible with Geo Stationary satellites only.

The SATRE Modem can be easily integrated into an existing satellite earth station. Turnkey systems for Ku-Band links are available as option. Radio Frequency power requirements are very low and transmissions can use "occupied" transponder channels without significant degradation or interference to the primary transponder user. Spread spectrum signals ensure compatibility with other services. It is possible to simultaneously operate several Modems using a single satellite transponder channel.

The signal links are designed to compensate for most of the unknown delays in signal propagation path and within the satellite transponder. Ranging information about the transponder is obtained at the same time. System integrity data and time information are distributed on the same RF links as the time signals. Fiber-optical links may be used as an alternative for very short to medium distance links.

Each SATRE Modem has an external data interface to communicate further the user and range information.

The SATRE Modem can contain up to three receiver channels, which operate independently and simultaneously. The system can be configured in different combinations. For eg. One channel can be assigned to receive the own re-transmitted signal and the remaining two channels can receive signals from remote sites. The unique combination of time and data transmission in one instrument allows efficient time synchronisation and maintenance of large networks.
### Specifications

#### Spread Spectrum Capabilities
- **Chiprates**: 0.5, 1, 2.5, 5, 10 and 20 MChip/s
- **Number of PN Codes**: 16 predefined (20 and 10 MChip/s), 32 predefined (5 MChip/s and below), user codes \( \rightarrow \) contact factory
- **Compatibility**: MITREX compatible on 2.5 MChip/s, codes 0..7

#### Transmitter

<table>
<thead>
<tr>
<th></th>
<th>SATRE mode</th>
<th>MITREX mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>Center frequency</td>
<td>70 MHz ± 15 MHz(^1)</td>
<td>70 MHz ± 15 MHz</td>
</tr>
<tr>
<td>Tuning resolution</td>
<td>0.001 Hz</td>
<td>0.001 Hz</td>
</tr>
<tr>
<td>Bandwidth</td>
<td>1.5 ( \times ) Chiprate (-6 dB)</td>
<td>2.6 MHz (-7 dB)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3.5 MHz (-17 dB)</td>
</tr>
<tr>
<td>RF output level</td>
<td>0 .. –40 dBm</td>
<td>0 .. –40 dBm</td>
</tr>
<tr>
<td>RF output (CW)</td>
<td>0 .. –30 dBm</td>
<td>0 .. –30 dBm</td>
</tr>
<tr>
<td>Output Impedance</td>
<td>50 Ω</td>
<td>50 Ω</td>
</tr>
</tbody>
</table>

#### Receiver

<table>
<thead>
<tr>
<th></th>
<th>SATRE mode</th>
<th>MITREX mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>Center frequency</td>
<td>70 MHz ± 15 MHz(^1)</td>
<td>70 MHz ± 15 MHz</td>
</tr>
<tr>
<td>Tuning resolution</td>
<td>Continuous</td>
<td>Continuous</td>
</tr>
<tr>
<td>Frequency</td>
<td>0.001 Hz (1 sec integration)</td>
<td>0.001 Hz (1 sec integration)</td>
</tr>
<tr>
<td>measurement</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Input Bandwidth</td>
<td>30 MHz (&gt; 2.5 MChip/s)</td>
<td>7 MHz</td>
</tr>
<tr>
<td></td>
<td>7 MHz (≤ 2.5 MChip/s)</td>
<td></td>
</tr>
<tr>
<td>Input Level (S + N)</td>
<td>-20 .. –60 dBm</td>
<td>-20 .. –60 dBm</td>
</tr>
<tr>
<td>Input Level (Signal)</td>
<td>-50 .. –75 dBm</td>
<td>-50 .. –75 dBm</td>
</tr>
<tr>
<td>optimum</td>
<td>-50 .. –60 dBm</td>
<td>-50 .. –60 dBm</td>
</tr>
<tr>
<td>Input Impedance</td>
<td>50 Ω</td>
<td>50 Ω</td>
</tr>
<tr>
<td>Number of channels</td>
<td>1 to 3</td>
<td>1 to 3</td>
</tr>
<tr>
<td></td>
<td>(Completely independent)</td>
<td>(Completely independent)</td>
</tr>
</tbody>
</table>

#### Signal Input

- **Signal input**: N
- **Reference Frequency**: BNC, 5 / 10 MHz, +3 .. +10 dBm
- **Pulse reference**: 1pps, rising slope, trigger level 0.4V programmable, impedance 50 Ω / 2kΩ selectable
- **Time reference**: NTP (RJ45, 10 Mbit/s)

#### Signal Output

- **Signal output**: N
- **Time pulses**: 0.4V unloaded, impedance 50 Ω
- **Tx**: PPS, Frame Rate, PN sequence
- **Rx**: PPS, Frame Rate
- **Tx Monitor**: fixed output (Tx signal) –10 dBm

\(^1\) ±15 MHz tuning range for 5 MChip/s and below, ±10 MHz for 10 and 20 MChip/s.
Guaranteed performance

Signal acquisition* > 44 dBHz, ≤ 5 MChip/s: < 30 sec
> 44 dBHz, > 5 MChip/s: < 150 sec
Signal acquisition using lookup tables* < 20 sec
Signal acquisition, high sensitivity mode* 40 dBHz, < 5 MChip/s; < 90 sec
40 dBHz, > 5 MChip/s; < 260 sec
Signal tracking in carrier lock* > 36 dBHz
Carrier frequency preset* ± 500 Hz from actual,
± 800 Hz (3 dB degradation)

This performance data is guaranteed by system test, which is part of factory acceptance test.

* tested with input signal at –30 dBm and ranging signal between –50 dBm and –75 dBm

Data interface

Physical RS232 (19200 bps) or network (TCP, UDP)
Contents Delay measurements, first, second, third order regression, real time estimate, system health status, …
Output rate 1 / second maximum.
Internal database 1 / minute, averaged values from delay and real time solution up to 90 days with integrated hard disk

Data recorded in internal data base

Ranging mode:
Measurement (minutely mean), Jitter, C/No, Signal Power, Current Configuration, Receiver Frequency, Pseudorange (Slant Range) if Modem is used in slave mode
TWSTFT:
Measurement (minutely mean), jitter, C/No, Signal Power, Current Configuration, Receiver Frequency, External Delay (RefDelay), Real Time TWSTFT delay estimation
Time sync:
Same data as TWSTFT plus clock model (estimated offset of steered clock)

RF data transfer

All relevant data embedded in RF signal, can be monitored / decoded by remote station. A system of SATRE’s does not need to be connected to each other; all necessary data is exchanged by RF.
Functions (TWSTFT mode)
Round trip delay  0 .. 600 ms
Resolution @ 1 s  10 ps
Stability    ≤30 ps/day (Tx, Rx, Tx-Rx)
Thermal stability ≤30 ps/K (Tx, Rx, Tx-Rx)
Measurements Round trip delay, real time TWSTFT

Functions (Ranging mode)
Round trip delay  0 .. 200000 km
Resolution @ 1 s  0.3 cm (round trip)
Stability    ≤1 cm/day
Thermal stability ≤1 cm/K
Measurements Round trip, pseudo range (slave mode)

Functions (TimeSync mode)
Round trip delay  0 .. 600 ms
Resolution @ 1 s  10 ps
Stability    ≤30 ps/day (Tx, Rx, Tx-Rx)
Thermal stability ≤30 ps/K (Tx, Rx, Tx-Rx)
Slave Oscillators  OCXO$^2$  Caesium$^3$  Other External
                   (External)  References
Frequency     < 10$^{-14}$/day  < 10$^{-14}$/day  Contact Factory
Time Stability < 250 ps  < 250 ps

Features:
Real time data evaluation (max. 5 seconds delay)
High resolution receive frequency measurement (0.001 Hz resolution at 1 second)
500 MB integrated hard disk
Internal time interval counter for RefDelay measurement. Note: In Ranging mode, this feature is not required and there is no data output provided.
Integrated GPS receiver as time source.
Interface to External 5/10 MHz and Coherent 1pps Reference Signal like Caesium, Masers etc.
I/F to Comtech and SSE G/S transceivers.
I/F to SATSIM station delay monitor.
GPS Disciplined OCXO for stand alone time & frequency reference **

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$^2$ Based on Continuous 24 hrs operation.
$^3$ Based on regular measurements via TWSTFT, 2.5 MChip/s, quarter-hourly, at least 5 minutes per run, C/No > 50 dBHz. Ground station stability is not accounted in these figures
** Option: Can be delivered without the OCXO for Time Labs using high quality reference source.
Satellite Time and Ranging Equipment (SATRE)

### Electrical interface
- **Supply voltage AC**: 110 V AC±10%, 50 to 60 Hz
  
  230 V AC±10%, 50 to 60 Hz

- **Power Consumption**:
  - SATRE 1 Channel #10140 < 80 W
  
  SATRE 2 Channel #10139 < 100 W
  
  SATRE 3 Channel #10221 < 125 W

### Transportation and Storage
- **Temperature, Humidity**: -20°C to +75°C, 10% to 90% (non condensing)
- **Shock**: Max 10g acceleration for 11 ms
- **Vibration**: Max. 0.15 mm at 5 to 8 Hz, Max 1g acceleration at 8 to 500 Hz
- **Altitude**: 12 000 m

### Operation
- **Temperature**: Operational 0°C to +50°C
  
  Full spec +15°C..+30°C

- **Humidity**: 20% to 90% (non condensing)

- **Altitude**: 2000 m

### Mechanical
- **Outline, Weight**: 19 inch, 4 height units (448.8 mm x 88 mm)
  
  Depth 448 mm, 17 kg
### Configuration Overview

<table>
<thead>
<tr>
<th>Item</th>
<th>SATRE Ranging</th>
<th>SATRE TWSTFT</th>
<th>SATRE TimeSync</th>
</tr>
</thead>
<tbody>
<tr>
<td>Second receiver channel</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(✓ integrated, ♦ selectable as option, ✗ not possible)

### Ranging Jitter [cm, one-way]

<table>
<thead>
<tr>
<th>C/No</th>
<th>ChipRate [MChip/s]</th>
<th>20</th>
<th>10</th>
<th>5</th>
<th>2.5</th>
<th>1</th>
<th>0.5</th>
</tr>
</thead>
<tbody>
<tr>
<td>40</td>
<td></td>
<td>5.3</td>
<td>10.6</td>
<td>21.2</td>
<td>42.4</td>
<td>106.1</td>
<td>212.1</td>
</tr>
<tr>
<td>42</td>
<td></td>
<td>4.2</td>
<td>8.4</td>
<td>16.9</td>
<td>33.7</td>
<td>84.3</td>
<td>168.5</td>
</tr>
<tr>
<td>44</td>
<td></td>
<td>3.3</td>
<td>6.7</td>
<td>13.4</td>
<td>26.8</td>
<td>66.9</td>
<td>133.8</td>
</tr>
<tr>
<td>46</td>
<td></td>
<td>2.7</td>
<td>5.3</td>
<td>10.6</td>
<td>21.3</td>
<td>53.2</td>
<td>106.3</td>
</tr>
<tr>
<td>48</td>
<td></td>
<td>2.1</td>
<td>4.2</td>
<td>8.4</td>
<td>16.9</td>
<td>42.2</td>
<td>84.5</td>
</tr>
<tr>
<td>50</td>
<td></td>
<td>1.7</td>
<td>3.4</td>
<td>6.7</td>
<td>13.4</td>
<td>33.5</td>
<td>67.1</td>
</tr>
<tr>
<td>60</td>
<td></td>
<td>0.5</td>
<td>1.1</td>
<td>2.1</td>
<td>4.2</td>
<td>10.6</td>
<td>21.2</td>
</tr>
<tr>
<td>&gt;=75</td>
<td></td>
<td>0.2</td>
<td>0.4</td>
<td>0.7</td>
<td>1.4</td>
<td>3.6</td>
<td>7.2</td>
</tr>
</tbody>
</table>

Typical ranging performance depending from chiprate and C/No. Unit is cm one-way

### TWSTFT Jitter [ns, round trip]

<table>
<thead>
<tr>
<th>C/No</th>
<th>ChipRate [MChip/s]</th>
<th>20</th>
<th>10</th>
<th>5</th>
<th>2.5</th>
<th>1</th>
<th>0.5</th>
</tr>
</thead>
<tbody>
<tr>
<td>40</td>
<td></td>
<td>0.4</td>
<td>0.7</td>
<td>1.4</td>
<td>2.8</td>
<td>7.1</td>
<td>14.1</td>
</tr>
<tr>
<td>42</td>
<td></td>
<td>0.3</td>
<td>0.6</td>
<td>1.2</td>
<td>2.3</td>
<td>5.6</td>
<td>11.2</td>
</tr>
<tr>
<td>44</td>
<td></td>
<td>0.3</td>
<td>0.5</td>
<td>0.9</td>
<td>1.8</td>
<td>4.5</td>
<td>8.9</td>
</tr>
<tr>
<td>46</td>
<td></td>
<td>0.2</td>
<td>0.4</td>
<td>0.8</td>
<td>1.5</td>
<td>3.6</td>
<td>7.1</td>
</tr>
<tr>
<td>48</td>
<td></td>
<td>0.15</td>
<td>0.3</td>
<td>0.6</td>
<td>1.2</td>
<td>2.8</td>
<td>5.6</td>
</tr>
<tr>
<td>50</td>
<td></td>
<td>0.1</td>
<td>0.2</td>
<td>0.5</td>
<td>0.9</td>
<td>2.3</td>
<td>4.5</td>
</tr>
<tr>
<td>60</td>
<td></td>
<td>0.05</td>
<td>0.1</td>
<td>0.2</td>
<td>0.3</td>
<td>0.7</td>
<td>1.4</td>
</tr>
<tr>
<td>&gt;=75</td>
<td></td>
<td>0.02</td>
<td>0.03</td>
<td>0.05</td>
<td>0.1</td>
<td>0.3</td>
<td>0.5</td>
</tr>
</tbody>
</table>

Typical measurement jitter depending from chiprate and C/No. Unit is ns roundtrip
Time Syncronisation Principle

- Master Clock
- SATRE
- Remote clock monitoring data
- Two-Way Link
- Time Signals Data Exchange
- SATRE Clock synchronised to Master Clock
- T & F Outputs:
  - Frequency
  - 1 pps
  - Date & Time
  - Corrective data

Two-Way Link

- Time Signals
- Data Exchange
- Remote clock monitoring data

TimeSync setup (left) and verification (right)

TimeSync Synchronisation Performance

Typical Frequency Stability (Allan Deviation) via satellite, corrective data applied. Continuously locked over satellite; 5 MChip/s. Master clock was maser, slave clock OXO OSA 8607 (high performance 5 MHz S/C cut oscillator). Ramp for $10^4$ seconds is due to ground station instabilities.