TSIM Manual

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1 Introduction

TSIM is a transponder signal simulator to be used in conjunction with TBAD (transponder-based aircraft detector) in an observatory setting. TSIM provides aircraft-like pulse patterns across a range of signal strengths. Together with telescope pointing, TSIM can:

- verify that TBAD is capable of receiving and reacting to signals
- check the sensitivity to theoretical and to empirical/historical expectations
- map out the angular response
- verify proper handling of saturation signals
- verify proper activation holdoff (N pulses required to activate shutter)

TSIM employs a number of modes to test these various features. Modes may be selected one at a time using the mode knob, or a "medley" mode setting is also available that cycles through key modes in a repeating sequence to provide a full sampling of tests. This mode is intended to be the default mode for normal observatory operations.

Please refer to the list of abbreviations and acronyms at the end to resolve any ambiguities.

2 Physical Interface

The TSIM package was designed to have as simple an interface as possible, the idea being that tests could be carried out by simply applying AC power by a remote-controlled relay or IP switch. The knobs are inside of a sealed box, so that only the AC input (IEC 320 C-13) and RF output (BNC) are externally available.

Internally, an ON/OFF switch and two setting knobs are available. as well as an LED that blinks each time an RF pulse sequence is produced. The knobs go by the name of Mode and Parameter. Each has a range of 0–15, and may be rotated continuously (can go from 15 to 0 without going the long way back around).

Table 1: Mode Settings

Mode #	Mode Name	Description	Parameter Interpretation
0	Medley	repeating sampling	varied
1	Full ramp	every power level explored	no effect
2	Weak ramp	only sub-threshold power levels	sets peak signal
3	N-moderate	produce N moderate-strength packets per frame	sets N
4	High-rate moderate	50 Hz rate at moderate strength	signal level
5	High-rate background	produce N moderates in sea of weak	sets N
6	Variable rate	moderate-level packets emitted at fixed rate	sets rate
7	Empty	nothing happens: a way to turn off output	no effect
8	Strong packet	single high-strength packet per frame	signal level
9	2-per-frame	two packets per frame	signal level
10	5-per frame	five packets per frame	signal level
11	10-per frame	ten packets per frame	signal level
12	20-per-frame	twenty packets per frame	signal level
13	50-per-frame	fifty packets per frame	signal level
14	100-per-frame	100 packets per frame	signal level
15	500-per-frame	500 packets per frame	signal level

3 Operational Modes and Principles

The Mode knob selects the overall operational mode of TSIM. For most modes, the **Parameter knob** controls some aspect of the behavior, although its interpretation is **context-dependent**, depending on the mode. When controlling power levels, the higher number always corresponds to higher power.

Table 1, at first glance, may generate more questions than it answers. First, some terminology.

TSIM operation can be divided into two fundamentally different mode types. **Manual mode** covers mode knob settings from 1–15. **Medley mode** pertains to the mode knob setting of 0. Medley mode rotates through a sequence of behaviors, each one separately accessible in manual mode. It is not unusual for the parameter knob to carry different meanings in manual vs. medley mode.

TSIM operates on the principle of **frames**. A frame lasts ten seconds. When a frame is done, either the same behavior repeats (manual mode), or a new behavior is selected (medley mode). Every frame in medley mode begins with a **heartbeat** signal: a moderate-level single pulse to announce the beginning of a frame and ensure that TBAD can hear *something*. Depending on the behavior, a two second pause may be appended to each frame. The rationale is to give TBAD a chance to relax the shutter before a new shutter-closing offense is inflicted.

Signal levels are characterized as **weak**, **moderate**, or **strong**. Weak signals are not expected to exceed the TBAD DT threshold. Thus even if in the center of the beam, TBAD will deem the signal too weak to create a shutter trigger. For normal TBAD settings, weak signals will be invisible, and not make an entry in the log. Moderate signals are meant to have a high enough level to surpass the DT threshold, and therefore create a shutterable offense and a TBAD log entry. The TBAD-controlled shutter will only close after NB events have been recorded in the last 10

minutes, depending on the knob setting on the front of the TBAD decoder unit (NB represents N "in-beam" events in 10 seconds). Strong signals could potentially cross the saturation thresholds (DS and OS), depending on level and settings. A single saturation event will close the shutter.

Programmable attenuators within TSIM provide 32 possible signal levels, in steps of 2 dB (a factor of 1.58 per step, corresponding to aircraft distance steps in factors of 1.26). At TBAD, each 2 dB step corresponds to 0.05 V with respect to the various thresholds. In other words, changing any threshold by 0.1 V corresponds to two steps of TSIM signal level adjustment, or 4 dB in signal strength.

Each transmission has an associated code. They all share the common features that the first framing pulse (mandatory) is present, and also the X bit, but no final framing pulse. This makes the TSIM signals look different from any legitimate aircraft transmission. There are four octal digits also associated with each transmission. The first two (AB) indicate the mode, and the second two (CD) relate the power level. Certain constraints are imposed on possible codes, so that particular emergency and common aircraft codes may be avoided. For instance, the D digit always has the least-significant bit set, to avoid the possibility of a code ending in zero. Thus D will always be odd. Likewise, the middle bit on A is never set, so only 0, 1, 4, and 5 are possible A digits. When the most significant bit in A is set (4 or 5, in practice), this indicates that the current behavior is being accessed from the medley mode, as opposed to manual mode (direct knob setting).

Now we have the language to discuss operating modes in more detail.

3.1 Full Ramp: Knob Position 1

The full ramp visits every TSIM output power in steps of 2 dB, going from the weakest to the strongest in the first five seconds of the frame, then descending through the same sequence over the following 5 seconds. The parameter knob has no effect. A two second pause is inserted at the end. The AB code is either 01 or 41, depending on whether the ramp is accessed from the mode knob (in position 1) or via medley mode, respectively. CD values will ascend through 01, 03, 05, 07, 11, ..., 67, 71, 75, 77 before descending through the same 32-bit sequence. Only the top of the "mountain" will be recorded by TBAD, which is useful for elucidating the signal level corresponding to threshold settings. The parameter knob has no effect.

3.2 Weak Ramp: Knob Position 2

The weak ramp is very similar to the full ramp—stepping through power output in 2 dB steps—except that it does not ascend all the way to the maximum signal. In manual mode, the parameter knob sets the maximum signal level, the 16 positions covering the lowest 16 power settings of TSIM in 2 dB steps. In medley mode, the peak power is hard-coded in the software, and not responsive to the parameter knob position. Packets are sent at a fixed cadence, so that a weaker ramp completes more quickly than a stronger one (more steps in the stronger sequence). A two-second pause appears at the end of the weak ramp. Because the level may typically be below TBAD thresholds, the frame may appear to be empty besides the heartbeat packet. The AB code is 02, or 42 if accessed via medley mode.

3.3 N-Moderate: Knob Position 3

Produces N packets of moderate-strength at a fixed cadence. The purpose is to test that TBAD closes the shutter on the NBth packet, as set on the TBAD front panel. The strength is hard-coded, and the parameter knob sets the value for N. The pattern corresponds exactly to the TBAD knob settings, running through the sequence: 0, 1, 2, 3, 4, 5, 6, 8, 10, 12, 15, 20, 25, 30, 35, 40. Nominally, you would want the parameter knob to match the setting of the TBAD knob. In medley mode, this sequence is applied with one less packet than the setpoint ($N - 1$), then the exact number (N), and later one plus the setpoint ($N + 1$). This checks that TBAD does *not* trigger on $NB - 1$, but does on NB or more. The heartbeat is factored into the calculation, looking just like the other moderate packets. The AB code is 03 in manual mode, 43 in medley mode.

3.4 High-Rate Moderate: Knob Position 4

Sends out pulses at 50 Hz to check that TBAD can respond to high-rate signals. In manual mode, the parameter knob controls the signal strength, covering the middle 16 possible values in steps of 2 dB. In medley mode, the strength is hard-coded and the parameter knob ignored. The AB code is 04 in manual mode, 44 in medley mode.

3.5 High-Rate Background: Knob Position 5

Intended to check that TBAD can respond to shutterable offenses in the midst of a high background rate, this mode provides a flood of weak signals (signal strength hard-coded) with interspersed moderate signals (also hard-coded strength). The parameter knob sets the number of moderate packets in the frame, just as for mode 3 (following TBAD NB knob sequence). In medley mode, the number is adjusted to accommodate the heartbeat. Note that unless the OT is set to accept weak signals, the background will be unobservable, and therefore does not constitute a novel test for TBAD beyond what happens in mode 3. The AB code is 05 in manual mode, or 45 in medley mode.

3.6 Variable Rate: Knob Position 6

Ten moderate-strength packets are emitted at a variable rate. Manual mode produces rates from 10–160 Hz, in steps of 10 Hz. For instance, a parameter knob setting of 5 will produce a 60 Hz rate. In medley mode, the rate is adjusted with the passing of each second of time. So within the ten second frame, the first second sees 10 Hz, the second second sees 20 Hz, etc., ending at 100 Hz. The AB code is 06, or 46 in medley mode.

3.7 Empty: Knob Position 7

Some friends need an OFF switch, and that's effectively what this mode provides: it shuts TSIM up. This can be potentially useful in giving TBAD enough time to open the shutter after some barrage, or to silence the unit for other in-dome testing purposes. In medley mode, the heartbeat will still survive. The AB code is 07 (were there to be packets sent!), and 47 in medley mode.

3.8 Strong Packet: Knob Position 8

A single high-strength packet is emitted per 10 second frame, allowing tests of saturation limits and single-event shuttering in response. In manual mode, the strength is set by the parameter knob, in steps of 2 dB, spanning the top 16 values in the full range. In medley mode, the strength is hard-coded. The two-second rest at the and of the frame is preserved in both manual and medley modes, to give TBAD time to open the shutter. The AB code is 10 in manual, 50 in medley.

3.9 Two Per Frame: Knob Position 9

This setting emits two packets in each frame, equally separated, and with no two-second rest at the end (in manual mode), giving a steady 0.2 Hz rate. In medley mode, the signal strength is hard-coded to be moderate. In manual mode, the signal strength is adjustable across the full range, in steps of 4 dB. The AB code is 11 in manual mode, 51 in medley mode.

3.10 Five Per Frame: Knob Position 10

This setting behaves just like the previous, but with five packets in each frame, giving a steady 0.5 Hz rate in manual mode. The AB code is 12 in manual mode, 52 in medley mode.

3.11 Ten Per Frame: Knob Position 11

This setting behaves just like the previous, but with ten packets in each frame, giving a steady 1 Hz rate in manual mode. The AB code is 13 in manual mode, 53 in medley mode.

3.12 Twenty Per Frame: Knob Position 12

This setting behaves just like the previous, but with 20 packets in each frame, giving a steady 2 Hz rate in manual mode. The AB code is 14 in manual mode, 54 in medley mode.

3.13 Fifty Per Frame: Knob Position 13

This setting behaves just like the previous, but with 50 packets in each frame, giving a steady 5 Hz rate in manual mode. The AB code is 15 in manual mode, 55 in medley mode.

3.14 One-Hundred Per Frame: Knob Position 14

This setting behaves just like the previous, but with 100 packets in each frame, giving a steady 10 Hz rate in manual mode. The AB code is 16 in manual mode, 56 in medley mode.

3.15 Five-Hundred Per Frame: Knob Position 15

This setting behaves just like the previous, but with 500 packets in each frame, giving a steady 50 Hz rate in manual mode. The AB code is 17 in manual mode, 57 in medley mode.

4 Medley Mode

As currently programmed, medley mode runs through the following sequence:

1. Full Ramp
2. Weak Ramp
3. N-moderate with $N = NB - 1$
4. N-moderate with $N = NB$
5. Weak Ramp
6. N-moderate with $N = NB + 1$
7. Weak Ramp
8. Strong Packet with strength $>$ DS
9. Strong Packet with strength $>$ OS
10. High-rate moderate with signal $<$ DT
11. High-rate moderate with signal $>$ DT
12. Weak Ramp
13. High-rate background with $N = NB$
14. Weak Ramp

The Weak Ramp is used as a filler when TBAD is expected to have closed the shutter and not had adequate time to recover (re-open) prior to the next frame.

5 Example Walk through the Medley

The encoding scheme should permit identification of the circumstances of any given packet's creation. The AB code corresponds to the mode in which the packet was generated (including distinction between medley and manual modes), so that the manual mode knob position may be known. The CD code is unique for each of the 32 transmit power levels. The X-bit should be present, and the final framing bit (F) missing. One should never see a value for A of 2, 3, 6, or 7. D should never be even.

The following are examples from preliminary tests on Keck-2, using firmware version 6. We'll look at each frame in sequence as the medley progresses. There are some anomalous behaviors, indicating in some cases the need to revisit and correct the firmware.

5.1 Step 1: Strong Ramp

First, we look at a sequence from the strong ramp, in medley mode:

```
2013-01-06, 22:30:16.911, o4141..BPFX.F3
2013-01-06, 22:30:16.913, o4143..BPFX.F5
2013-01-06, 22:30:16.913, s4145..BPFX.FB
2013-01-06, 22:30:16.934, s4147..BPFX.FD
2013-01-06, 22:30:17.095, s4151..BPFX.F8
2013-01-06, 22:30:17.255, s4153..BPFX.FA
2013-01-06, 22:30:17.415, s4155..BPFX.FC
2013-01-06, 22:30:17.575, s4157..BPFX.FE
2013-01-06, 22:30:17.735, s4161..BPFX.F9
2013-01-06, 22:30:17.900, s4163..BPFX.FB
2013-01-06, 22:30:18.015, s4165..BPFX.FD
2013-01-06, 22:30:18.175, s4167.DBPFX.15
2013-01-06, 22:30:18.335, s4171.DBPFX.10
2013-01-06, 22:30:18.495, s4173.DBPFX.12
2013-01-06, 22:30:18.655, s4175ODBPFX.35
2013-01-06, 22:30:18.815, s4177OD.PFX.23
2013-01-06, 22:30:18.975, s4177OD.PFX.23
2013-01-06, 22:30:19.135, s4175ODBPFX.35
2013-01-06, 22:30:19.294, s4173.DBPFX.12
2013-01-06, 22:30:19.415, s4171.DBPFX.10
2013-01-06, 22:30:19.575, s4167.DBPFX.15
2013-01-06, 22:30:19.735, s4165..BPFX.FD
2013-01-06, 22:30:19.895, s4163..BPFX.FB
2013-01-06, 22:30:20.055, s4161..BPFX.F9
2013-01-06, 22:30:20.215, s4157..BPFX.FE
2013-01-06, 22:30:20.375, s4155..BPFX.FC
2013-01-06, 22:30:20.535, s4153..BPFX.FA
2013-01-06, 22:30:20.695, s4151..BPFX.F8
2013-01-06, 22:30:20.855, s4147..BPFX.FD
2013-01-06, 22:30:20.975, s4145..BPFX.FB
2013-01-06, 22:30:21.135, s4143..BPFX.F9
2013-01-06, 22:30:21.295, s4141..BPFX.F7
```

We see that: 1) the pulses come out in a steady rate; 2) the shutter closed on the third detection ($NB = 3$); 3) the signals are all "in beam" (except when saturation interferes); 4) all have the characteristic "FX." sequence indicating that the X bit is on and the final F is off; 5) the mode is 41 (medley-requested full ramp); 6) the signal enters the DT-detectable range at a power corresponding to CD = 41, and thereafter counts up all the available odd octal digits to 77; 7) that the directional array begins to saturate at a power level corresponding to CD = 67, and the omni saturates at the top two power levels; 8) that the directional array becomes so saturated at the highest power level (77 is 8 dB, or 0.2 V higher than 67) such that the in beam assessment is predictably thwarted; 9) the response is symmetric; 10) no packets are missing; 11) a 4.5 second pause enters

at the end, before the weak ramp heartbeat comes along. Note that the moderate signal level was pre-programmed to come in at level CD = 41, which it turns out is just on the edge of the DT setting. Not as much margin as was intended.

5.2 Step 2: Weak Ramp

This one is empty, except for the heartbeat.

```
2013-01-06, 22:30:25.855, s4241..BPFX.F8
```

5.3 Step 3: N-moderate

Meant to be just two pulses (if NB set to 3), but came out as four, including heartbeat. Also notice they are piled right on top of each other.

```
2013-01-06, 22:30:34.293, s4341..BPFX.F9
2013-01-06, 22:30:34.294, s4341..BPFX.F9
2013-01-06, 22:30:34.295, s4341..BPFX.F9
2013-01-06, 22:30:34.295, s4341..BPFX.F9
2013-01-06, 22:30:44.095, o8888...P...B3
```

Not sure why the shutter was still closed at the beginning of the sequence: the last weak ramp should have supplied ample time to release the shutter hold. Sometimes if TBAD is kept really busy, the time counter is not allowed to advance. This always fails safe: the shutter is more likely to come on, and takes longer to turn off. Note that the time stamp is from the logging computer, not TBAD itself. At the end of the sequence, the shutter does open, ten seconds after the last offense, as expected.

5.4 Step 4: N-moderate

Meant to be 3 pulses (if NB = 3), but came out as four, including heartbeat. Again piled up, but at least started out with shutter open, closing on the third offense. The sequence starts 12 seconds after the previous one, as expected (ten second frame plus 2 second rest).

```
2013-01-06, 22:30:46.323, o4341..BPFX.F5
2013-01-06, 22:30:46.324, o4341..BPFX.F5
2013-01-06, 22:30:46.324, s4341..BPFX.F9
2013-01-06, 22:30:46.325, s4341..BPFX.F9
2013-01-06, 22:30:56.095, o8888...P...B3
```

5.5 Step 5: Weak Ramp

Time to rest. Only the heartbeat at the beginning is seen.

```
2013-01-06, 22:30:58.294, o4241..BPFX.F4
```

The shutter was already open before this mode came along.

5.6 Step 6: N-moderate

This one was meant to be four moderate pulses, and actually is. A broken clock is right twice a day, perhaps.

```
2013-01-06, 22:31:05.855, o4341..BPFX.F5
2013-01-06, 22:31:05.975, s4341..BPFX.F9
2013-01-06, 22:31:06.055, s4341..BPFX.F9
2013-01-06, 22:31:06.175, s4341..BPFX.F9
2013-01-06, 22:31:16.678, o8888...P...B3
```

Curiously, the shutter closes on the second, rather than third offense, but opens at the expected time.

5.7 Step 7: Weak Ramp

Time for rest. Shutter is already open.

```
2013-01-06, 22:31:17.855, o4241..BPFX.F4
```

5.8 Step 8: Strong Packet, DS Trigger

The heartbeat does not close the shutter, but the strong signal does, even though 65 is actually not strong enough to trip DS.

```
2013-01-06, 22:31:25.855, o5041..BPFX.F3
2013-01-06, 22:31:25.975, s5065..BPFX.FD
2013-01-06, 22:31:35.639, o8888...P...B3
```

5.9 Step 9: Strong Packet, OS Trigger

This time, a level of 75 is enough to trip both omni and directional antennas, closing the shutter in the process.

```
2013-01-06, 22:31:37.855, o5041..BPFX.F3
2013-01-06, 22:31:37.975, s5075ODBPFX.35
2013-01-06, 22:31:47.585, o8888...P...B3
```

5.10 Step 10: High Rate, Moderate, Signal $<$ DT

Because the signal was sub-threshold, only the heartbeat is heard.

```
2013-01-06, 22:31:49.855, o4441..BPFX.F6
```

5.11 Step 11: High Rate, Moderate, Signal $>$ DT

Open the floodgates.

```
2013-01-06, 22:32:02.911, o4441..BPFX.F6
2013-01-06, 22:32:02.913, o4441..BPFX.F6
2013-01-06, 22:32:02.913, s4441..BPFX.FA
2013-01-06, 22:32:02.914, s4441..BPFX.FA
2013-01-06, 22:32:02.914, s4441..BPFX.FA
2013-01-06, 22:32:02.914, s4441..BPFX.FA
2013-01-06, 22:32:02.914, s4441..BPFX.FA
:
2013-01-06, 22:32:11.775, s4441..BPFX.FA
2013-01-06, 22:32:11.815, s4441..BPFX.FA
2013-01-06, 22:32:11.815, s4441..BPFX.FA
2013-01-06, 22:32:11.855, s4441..BPFX.FA
2013-01-06, 22:32:11.855, s4441..BPFX.FA
```

A total of 495 events spanning about 9 seconds. The shutter closes on the third event, which is expected behavior.

5.12 Step 12: Weak Ramp

The usual heartbeat, and that's all.

```
2013-01-06, 22:32:14.278, s4241..BPFX.F8
```

5.13 Step 13: High Rate Background, $N = 3$

After the heartbeat, there are three moderate signals mixed in with (unseen) lower-strength signals at a high rate.

```
2013-01-06, 22:32:21.855, s4541..BPFX.FB
2013-01-06, 22:32:22.175, s4541..BPFX.FB
2013-01-06, 22:32:22.375, s4541..BPFX.FB
2013-01-06, 22:32:22.615, s4541..BPFX.FB
```

Shutter has been on through last few frames, for some reason.

5.14 Step 14: Weak Ramp

Same old story, but shutter is still on.

```
2013-01-06, 22:32:23.855, s4241..BPFX.F8
```

5.15 Now Repeat

Next comes the full ramp again. First we see the heartbeat, then a pause while the ramp is in the unseen low-signal territory, picking up again at level 41 and climbing.

```
2013-01-06, 22:32:32.407, s4141..BPFX.F7
2013-01-06, 22:32:34.455, s4141..BPFX.F7
2013-01-06, 22:32:34.615, s4143..BPFX.F9
2013-01-06, 22:32:34.775, s4145..BPFX.FB
2013-01-06, 22:32:34.935, s4147..BPFX.FD
```

And so it goes. The sequence took about 137 seconds to run its course.

6 List of Abbreviations and Acronyms

AB	refers to first two digits in the transmitted ABCD code, signifying operating mode
AC	Alternating Current
BNC	Bayonet Neill-Concelman: standard twist-lock co-ax connector
CD	refers to the last two digits in the transmitted ABCD code, signifying power level
DS	Directional Saturation threshold in TBAD
DT	Directional Threshold setting in TBAD, indicating an aircraft within protected zone
IP	Internet Protocol
LED	Light Emitting Diode
NB	Number of in-Beam events (in last 10 seconds) required for TBAD shutter to activate
OS	Omni Saturation threshold in TBAD
OT	Omni Threshold for logging single-patch detections
RF	Radio Frequency
TBAD	Transponder-Based Aircraft Detector
TSIM	Transponder SIMulator