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Mode-S Transponder Software Modifications

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Originator Code : EEC Division B2	Originator (Corporate Author) Name/Location : EUROCONTROL Experimental Centre B. P. 15 F - 91222 BRETIGNY SUR ORGE Cedex Telephone (1) 69 88 75 00
Sponsor Code : Engineering Directorate Division E1	Sponsor (Contract Authority) Name/Location : EUROCONTROL Agency 72, rue de la Loi B - 1040 BRUSSELS Telephone (2) 233 02 11

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Author : Mr. P. **HUNT**	Date	Pages	Figs	Refs	Annexes
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Abstract :

This note describes all the software modifications required to ensure that the **TRT** transponder meets the Mode-S specification.

The result will be a new Mod state for the transponder (Bulletin de Service), which should be applied by **THOMSON-TRT**.

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THOMSON - TRT
MODE-S TRANSPONDER SOFTWARE MODIFICATIONS

by

P. HUNT

S U M M A R Y

This note describes all the software modifications required to ensure that the **TRT** Transponder meets the Mode-S specification.

The result will be a new Mod state for the transponder (Bulletin de Service), which should be applied by **THOMSON-TRT**.

The source programs will be provided free of charge by **EUROCONTROL** for use by **THOMSON-TRT**.

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1. INTRODUCTION

During ground and air trials with the transponder over a few years various anomalies have been observed. The majority of these anomalies have been found to be due to software errors.

This note describes the errors and the modifications made to correct these errors.

During factory acceptance of the equipment, **TRT** (now **THOMSON-CNI**) provided **EUROCONTROL** with source listings of all the programs in the transponder.

The following modifications have been made by correcting the errors in the original programs and producing new EPROMS which have been tested in situ in the transponder.

To facilitate this work we have produced "pseudo source" programs from the original Proms in order to re-assemble all the programs more comfortably.

2. GENERAL

There are three microprocessors in the transponder : Two MOTOROLA 6809s and one TEXAS INSTRUMENT TMS 320 C1.

The 6809s are general purpose microprocessors and the TMS is a high speed signal processor.

There are three programs in the transponder :

(1) The TMS RF signal processing program which controls the Mode-S receive and transmit processes.

(2) The Main 6809 program which controls the general transponder functions.

(3) The Data Link 6809 program which communicates with the Data Link Processor.

These three programs are interdependent and communicate with each other, as follows :

(1) The TMS and Main 6809 exchange data through a common memory, the access of which is controlled by the TMS. The 6809 having access only when permitted by the TMS.

(2) The 6809 Main and 6809 Data Link programs exchange data through FIFOs.

3. EQUIPMENT USED FOR PROGRAM MODIFICATION

All work was done using a standard PC with in addition :

(1)	An Eprom programming system	13.900 FF-HT
(2)	A universal assembler machine for all types of micro-processors	6.500 FF-HT

All the transponder source programs are now available on a 3 1/2" 1.44 Mbyte IBM compatible floppy disc.

4. EFFORT REQUIRED

This work has taken about 14 man/months (**EUROCONTROL**), not including laboratory, field and flight testing made by **DRA** Malvern, **DRA** Bedford, **CENA** Athis-Mons to determine errors and validate solutions and radar commissioning tests carried out by **THOMSON** (Orly radar) and **EUROCONTROL** especially in the COMM-D domain.

5. DETAILS OF PROBLEMS ENCOUNTERED AND ACTION TAKEN

(1) The Mode-S TAS subfield was not reset after an 18 second timeout (TRC timer).

Reason :

Due to an omission to reset this field in the TMS program.

Action : Added

(2) Problems when radar trying to deliver uplink ELMs, particularly under poor transmission conditions (noise or antennas obscured).

Reason :

If initialising segments were received with bad parity certain variables were initialised before the parity was checked causing the ELM message to be corrupted.

Action :

The variables concerned were not initialised until after the Mode-S address parity was checked. This correction was also applied to the other ELM routines to ensure correct action.

(3) When radar sent an uplink ELM to the transponder the ELM data was repeatedly sent to the DLPU if further final segments were sent up by the radar. This can occur if no reply is received by the ground to the final segment transmission.

Reason :

When the transponder receives all the segments of an ELM it should ship out the message to the DLPU and then disable further transfers to the DLPU if other final segments are sent before another initial segment (new message) is transmitted. This was not being done.

Action :

The TMS routine for processing final segment reception was modified so that the 'SETUP' was disabled after shipping out one message to the DLPU.

(4) If the ground station requested a downlink ELM from the transponder when none was announced, the transponder would send the last one which was in the downlink ELM buffer.

Reason :

The transponder should reply with all downlink ELM data fields zero if it is not announcing an ELM ready to transmit. The transponder sets the Mode-S DR subfield to 15 plus the number of segments if a downlink ELM is ready for the ground. If the DR field is not >=16 the transponder should set the Mode-S MD fields to zero when replying to a request for downlink ELM delivery. This was not done.

Action :

The TMS routine for ELM downlink delivery was modified to test the DR field and transmit zeroes if DR < 16.

(5) It was found during laboratory tests with the DLPU that certain timeouts in the ARINC 718 protocol were not exact.

Reason :

Wrong constant values in Data Link program.

Action : Corrected.

(6) It was found that when the DLPU tried to downlink ELMs of more than 6 segments to the transponder they were not memorised by the transponder, and neither was there any error indicated to the DLPU at the ARINC 718 level.

Reason :

An ELM of more than six segments requires a multiple record transfer at the ARINC 718 level. This case was not being handled correctly by the Data Link program.

Action : Corrected.

(7) It was found that the SQUITTER did not always function correctly.

Reason : There were several errors in the TMS squitter program logic :

1) The squitter flag set by the 6809 Main could be reset by an intermode (all call) interrogation (P4 long).

2) A squitter was not output if the transponder was saturated (over interrogated or in an low power condition). The squitter should always be output or attempted.

3) The squitter interrogations were counted to determine transponder Mode-S output limits. This should not be done.

Action : Corrected.

(8) COMM-A Buffer Problem

Under certain conditions COMM-A messages (or COMM-C which are in the same buffer) are not output to the DLPU in the correct order. The buffer holds 10 messages, when an error occurs messages are output in the wrong order. The error stays until the transponder is reset.

The buffer is in common memory which is accessible by both the TMS 320 (RF signal processor) and the Main 6809 which processes messages and sends them to the data-link 6809 for transmission to the DLPU.

The buffer holds 10 messages of 8-16 bit words. Each message is stored as follows : Word 1 = Flag, Words 2 to 8 hold 56 bits or 112 bits of RF uplink message.

The flag is zero if message buffer is empty and 1 if it is filled.

The TMS tests the flag and if zero sets the flag and transfers a message to the message buffer and increments its writing pointer to next message, at the end of buffer the pointer is reset to the start of buffer.

The 6809 tests the flag and if set (one) transfers the message to the data link 6809 and resets the flag, incrementing its read pointer, at the end of buffer the read pointer is reset to the start of buffer.

It can be seen that under normal conditions the 10 flags in the COMM-A buffer must be either all zero (no messages to process) or all ones (buffer full) where TMS will then issue no reply to UF 20, 21 or 24 (data link messages) or reply to UF 4,5 messages (surveillance) but not transfer then to the COMM-A buffer, or there will be a series of one(s) followed by serie(s) of zeroes.

There should never be "holes" in the series of ones (i.e. 11011100001). If this occurs, it can be seen that messages will be output in the wrong sequential order !

This has been observed under certain conditions. Those conditions are when the test bench is sending bursts of COMM-A messages on the bottom antenna and the top antenna is being interrogated by other radars (military, SSR and Mode-S). The error occurs only in this noisy environment.

This is by far the most difficult problem we have had to investigate due to the fact that it was very difficult to reproduce the error.

Reason :

The reason why the flags are wrongly set was due to an incorrect control of the common memory accesses.

The common memory access are controlled by software. Under certain conditions this software control was not carried out correctly.

When the TMS main program is running it is interrupted when the RF circuitry detects a Mode-S interrogation. Control is passed to the interrupt program which then controls the common memory access. The TMS has priority when accessing the common memory and it must also tell the Main 6809 to not access the memory during this time. This is done by setting the IRQ (interrupt line of the 6809), during which time the 6809 idles if it requires common memory access.

When the main TMS program is running and processing a GICB (which requires common memory accesses), if at the same instant a Mode-S interrupt for a not specified UF format was received (which is possible when noise is processed), then a common memory "clash" was possible.

This was observed when a special measuring and recording device was connected to the transponder during testing. Due to the fact that the fault could only be detected some time after it occurred, several megabytes of data had to be recorded and analyzed.

This was done using a specially developed PC card and the DMA channel of the PC.

Due to this "clash", it is possible that the GICB processing as well as the COMM-A processing was corrupted.

Action :

The TMS program was modified to avoid these common memory access "clashes".

(9) Squitter validation problem

During testing squitter in the laboratory due to problems encountered whilst fitting transponders on commercial aircraft. It was noticed that the squitter transmission was not always validated correctly by the transponder.

Reason :

This was found to be due to the timing in the EINT3 (interrogation type 3) transmission logic. Due to propagation delays in the 4538 Monostable used in the transponder certain signals were being cut off too soon.

Action :

It was found by adjusting the timing slightly of this test sequence the problem could be overcome by software.

But it has been decided it would be better to replace this circuit with a faster one, this will be appended to BS6 and applied to all transponders by **THOMSON** as they are upgraded.

(10) BDS values extracted by the ground station are sometimes zero or sometimes fixed (static values) when the DLPU appears to be functioning normally.

Reason :

At present, unknown but probably linked with the COMM-A problems mentioned previously.

Action :

To be further tested when BS7 is installed with a DLPU in a commercial aircraft.

(11) Squitter transmissions

It was found that the squitter was not random enough. There were only four peak values over the range 800 ms to 1200 ms.

Reason :

The random number generator only gave four values and the squitter routine was incorporated in the auto test sequence which was called each 100 ms hence making it a time dependant task.

Action :

A new random number routine giving 400 states was written and the squitter transmission was incorporated as a background task in the Main 6809 program hence given a good random distribution from 800 - 1200 ms. See attached histograms in annex.

6. DETAILS OF OTHER CORRECTIONS

During the inspection, testing and re-assembly of three programs, many other discrepancies were noticed :

6.1. TMS Program

1) Unused code was removed.

2) Unused variables were removed.

3) Unused equates were removed.

4) Unused labels were removed.

5) In most of the real time subroutines the timing was verified and adjusted when necessary.

6) Many sections of code were shortened or re-written more efficiently, particularly in the critical real time interrupt areas.

7) Several errors in the code were corrected, some critical ! It must be stated that there are many code changes in this program (500 lines changed out of 5000) in addition to all the unused code and variables removed.

6.2. Main 6809 Program

As with the TMS program, several modifications were made :

1) Unused code removed.

2) Unused variables and equates removed.

3) Unused labels removed.

4) Several non-critical errors corrected.

There were about 120 lines of code changed in this program out of 6400 in addition to the unused code removed.

6.3. Data Link Program

As with the other two programs :

1) Unused code removed.

2) Identical subroutines with different names combined.

3) Unused variables and equates removed.

4) Double defined variables combined.

5) Several errors corrected, some critical for DLPU.

There were about 20 lines changed out of 2600 in addition to all the code removed.

7. MAIN 6809 PROGRAM

This program exists in two versions because originally **THOMSON** manufactured one series of transponders for the A320 and one series for **EUROCONTROL**.

The only difference between the two types of transponder was the polarity of the discrete to determine one or two antenna operation.

Nevertheless it has been found that certain modifications applied to the A320 version were not applied to the **EUROCONTROL** version.

This has been rectified and there are now only two lines of code which are different in the two versions.

Also, a conditional assembly directive has been included so that the two versions may be assembled from the same source hence reducing the number of sources to be kept and archived and also ensuring that any further modifications shall be correctly applied to both versions.

It is strongly recommended that in the future there is only one version of this program.

The version recommended is the one which adheres to the Mode-S norm for the antenna diversity.

Hence the discrete cabling would be the same on all aircraft types.

8. FUTURE MODIFICATIONS TO BE MADE

It has been found whilst searching for the previous problems that there are some errors, omissions or mis-interpretation of the Mode-S norms in the **TRT THOMSON** software. These are as follows :

(1) As mentioned earlier, the squitter logic was not correct and this has been improved. But in addition to these mods, the squitter is not transmitted if there is a suppression command from another equipment (DME).

This should be changed in so much as the squitter should be delayed and sent after the suppression pulse.

(2) The transponder should not reply to UF 11 (All call) whilst on the ground (recent change in the norm) but should reply to intermode interrogations whilst on the ground.

(3) The **THOMSON TRT** Transponder does not respect exactly the reply rate capabilities as laid down in the Mode-S specification. That is to say there is no distinction in the **TRT** software between the rates of short and long interrogation, because the same counters and timers are used for verifying both short and long interrogation rates. These should be separated and checked independently. Nevertheless, the COMM-D reply rate is checked correctly.

9. SPECIAL APPLICATIONS

(a) In addition to the above mentioned changes a special version of the Main 6809 processor program has been developed in which the aircraft altitude in Gillham code is processed. This was not done (nor required) in the original software.

Certain discretes on the aircraft cabling indicate to the transponder whether the altitude source data is from ARINC 429 sources or Gillham sources, hence this version remains compatible with the original software.

This version was developed for a specific application for the **DFS**.

(b) Another special version of the TMS program was developed for use with transponders modified by **EUROCONTROL** for 16 segment downlink capability.

The transponders were used for testing the **THOMSON** radar COMM-D capability and also for certain data link trials with **DRA**, **STNA**, and **CENA**.

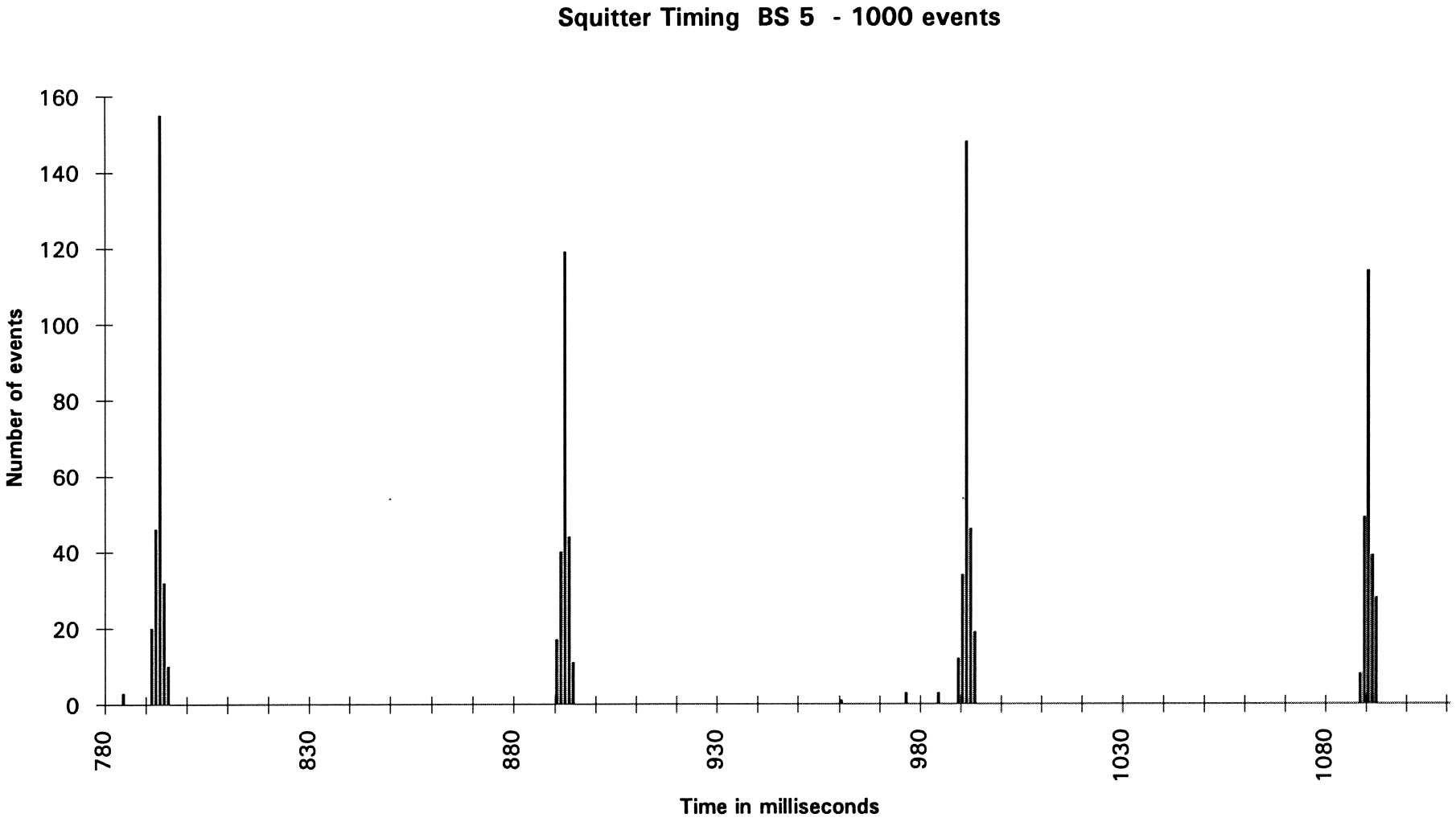
Squitter Timing BS 5 - 1000 events
Number of events
160
140
120
100
80
60
40
20
0
780
830
880
930
980
1030
1080
Time in milliseconds

Figure No. 1

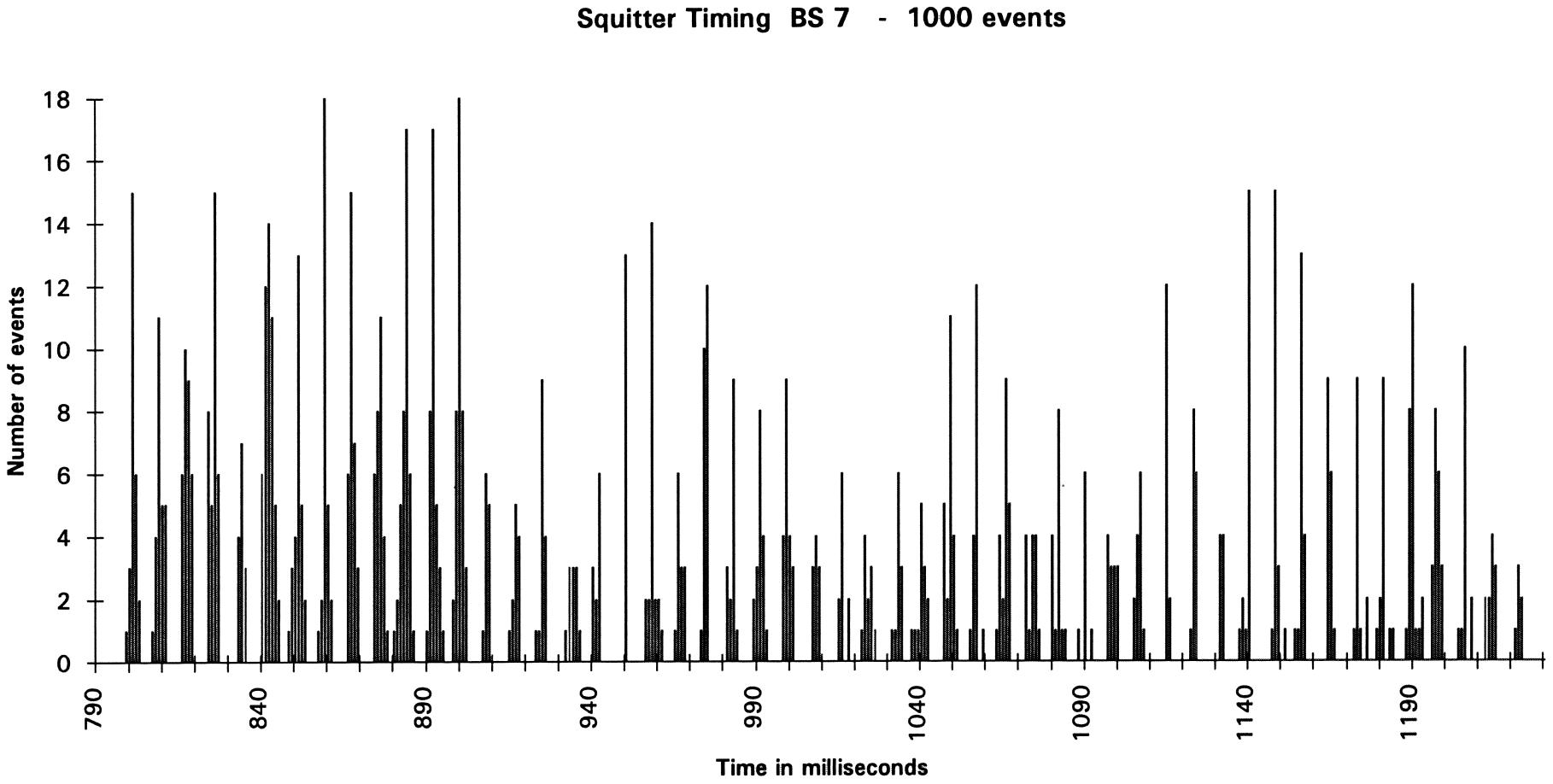
Squitter Timing BS 7 - 1000 events
Number of events
0
2
4
6
8
10
12
14
16
18
790
840
890
940
990
1040
1090
1140
1190
Time in milliseconds

Figure No. 2