# RTCA Special Committee 186, Working Group 3

## ADS-B 1090 MOPS, Revision A

## Meeting #14

# Non-Poisson Timing, and the Effects on Performance

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SUMMARY

The timing behavior of received ATCRBS fruit interference was discussed at the two previous meetings of WG-3. It has been shown that the timing is somewhat different from a Poisson process. Subsequently we at Lincoln have determined the effect of this behavior on Extended Squitter reception performance. This Working Paper describes the steps taken to incorporate the non-Poisson timing behavior in the Lincoln pulse-level simulation, and presents the resulting performance as a comparison between Poisson and non-Poisson behavior. The results indicate that reception performance does not change significantly.

## Non-Poisson Timing, and the Effects on Performance

The timing behavior of received ATCRBS fruit interference was discussed at the two previous meetings of WG-3. It was shown initially that results from the Volpe simulation differ somewhat from the behavior of a Poisson process. This was investigated more thoroughly by using airborne measurements. Processing data recorded airborne in the LA Basin, and also data recorded airborne in Frankfurt, Germany, non-Poisson behavior was also seen. The timing behavior was presented in the form of the histogram showing the number of fruit receptions in a 100 microsecond period. Whereas the Poisson process yields a bell shaped histogram, when the mean is about 2 or more, the measured histogram was similar but noticeably different. Specifically, whereas the variance of NF (number of fruit in 100 microsec) always equals the mean for a Poisson process, in the measured distributions, the variance was about 2 times the mean value. This finding seemed important because the pulse-level simulation used by Lincoln Laboratory is based on a Poisson process for fruit interference. Also, the bench test facilities at the Tech Center also have been used with Poisson timing for fruit interference.

It was decided therefore to proceed with this investigation by changing the models in order to determine the effects on reception performance. This paper presents the work done at Lincoln in changing the simulation model, and the resulting performance.

CHANGE IN SIMULATION MODEL

The pulse-level simulation at Lincoln, in its original form, generates ATCRBS fruit using a Poisson process model. Fruit reception times are generated in sequence, by generating the time between one fruit and the next using a random variable having an exponential distribution. The concept for changing this model was to retain the process that generates fruit times independently in sequence, but changing the distribution of TB, where

TB = time between one fruit and the next.

The approach is to generate successive values of TB independently. This approach is not entirely faithful, as is described below, but may provide a useful way of seeing whether significant changes in performance would result from non-Poisson timing behavior.

The first step was to determine the distribution of TB values. This was done using fruit data recorded airborne in LA. We used a file of 20,000 ATCRBS fruit receptions (only about 1 second of data) which was recorded at the time of maximum fruit rate. The power levels for fruit used in this analysis was limited to receptions of -84 dBm (at antenna) and stronger. We analyzed this file to determine the distribution of TB values.

Figure 1 shows the resulting distribution, giving a comparison with Poisson behavior. The upper plot shows the cumulative probability distribution. The lower plot show the same data but with a change in vertical scale. Instead of plotting P = cumulative probability, the ordinate is

$$\text{Ordinate} = -\ln(1 - P)$$

This change is convenient because the Poisson behavior appears as a straight line, and the actual distribution appears as a curved line that is similar to the straight Poisson behavior.

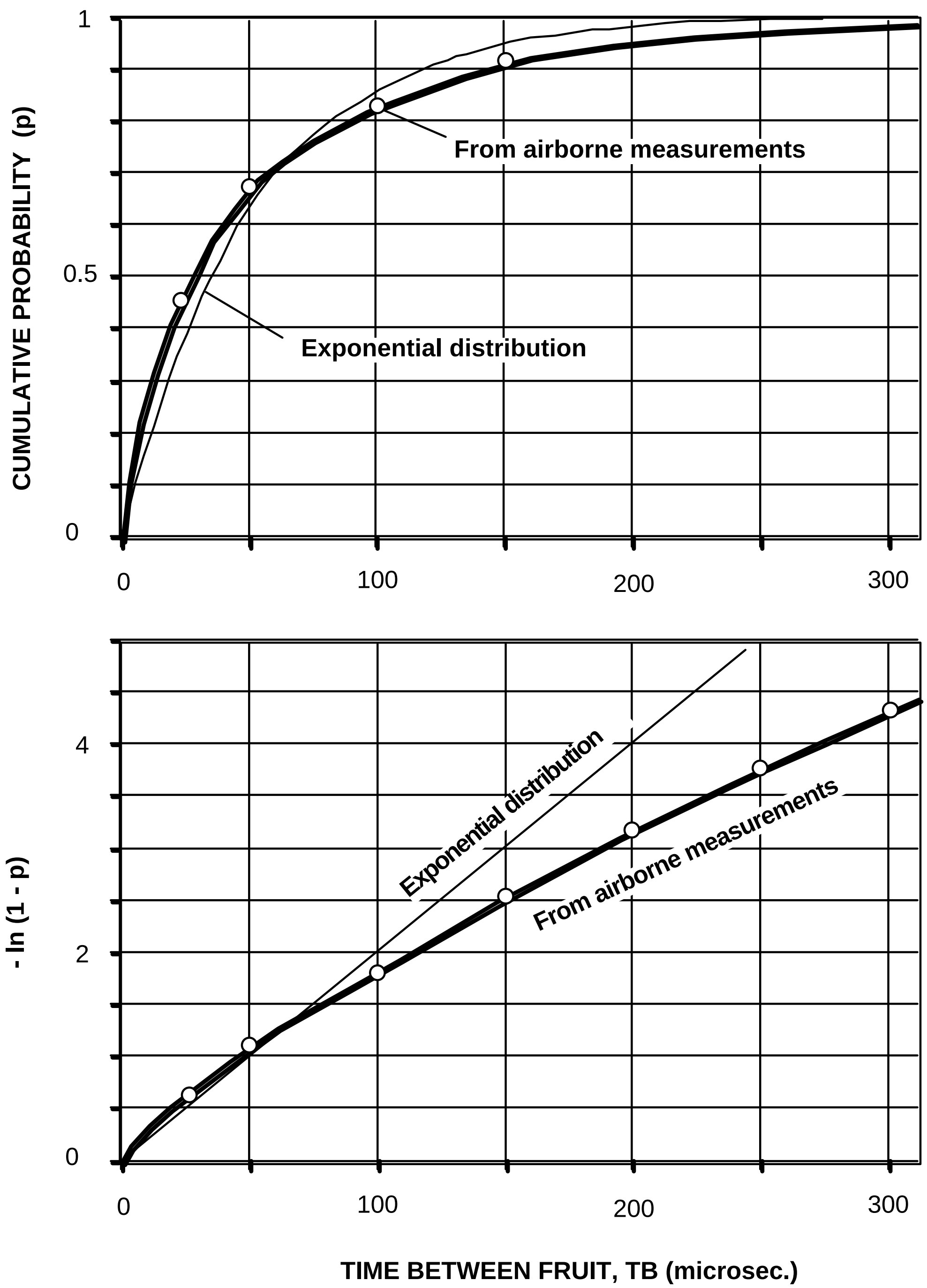


Figure 1. Comparison between Poisson and measured behavior.

To install a change in the pulse-level simulation, we developed a formula fitted to the data in Figure 1. The following formula was used.

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|---|
| Generate a random number x, from a uniform distribution over (0,1). |
| Let z = ln(1-x) |
| TB = F1(x) if x < 0.5<br>= F2(z)otherwise |
| where |
| F1(x) = 16.663*x + 29.577 * x^2 + 67.825 * x^3 |
| F2(z) = -17.037 - 55.963 * z + 4.111 * z^2 |

This formula applies to the particular fruit rate in the airborne measurements, which was 19,600 fruit/sec. In applying this model to other fruit rates, we scaled the TB value in proportion to the reciprocal of the fruit rate.

Low and High Power Fruit. We also gave some consideration to the possible distinction between fruit above -84 dBm (which was used to generate this new timing formula), and the weaker fruit, which is received at substantially higher rates. We came to the conclusion that if we applied the above process to the collection of all fruit, then the fruit above -84 dBm would not have the intended distribution. Therefore we decided to implement the above distribution in two parts. Fruit above -84 dBm was generated using the TB distribution given above, and fruit below -84 dBm was generated separately using the same timing distribution. Then the total of all fruit was applied to the receiver.

## NEW SIMULATION RESULTS

The simulation was run using this new fruit model for the fruit-rate conditions of Frankfurt under maximum current conditions. This is the condition used in the European report (ref. 1), whose performance is shown in Ref. 1, Figure 6 (page 97). The selection of a particular scenario is somewhat arbitrary, but this choice seems reasonable for seeing how the non-Poisson timing behavior may affect performance.

The results are shown in Figure 2.

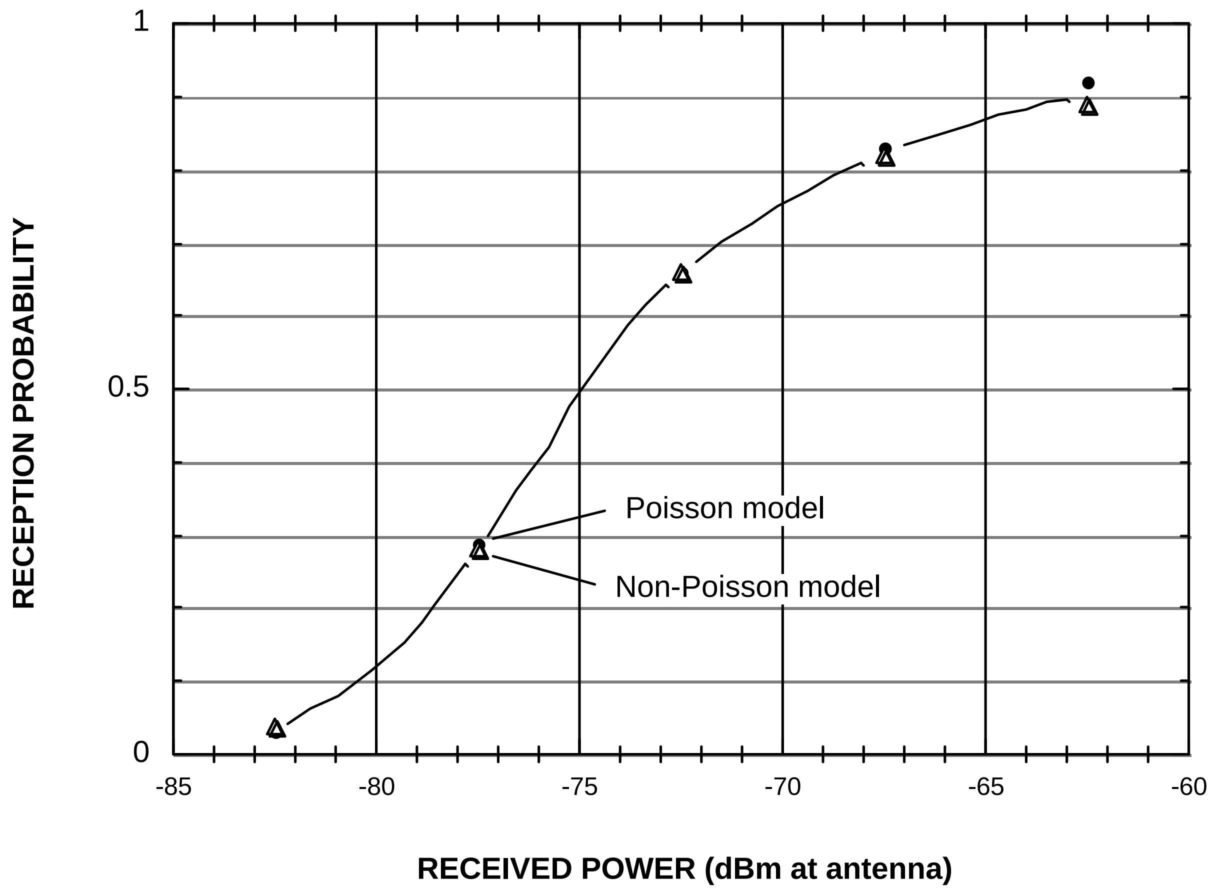


Figure 2. Simulation results comparing the new and old models.

The results in Figure 2 indicate no significant difference in performance between the Poisson model and the new non-Poisson model. Evidently the benefits that result from increased probability of long gaps between fruit are balanced by degradations that result from decreased probability of having one or two fruit overlaps. When all of the possible conditions are considered together, the consequence appears to be that there is no significant change in performance.

## LIMITATION IN THIS APPROACH

As mentioned above, the approach used in this analysis was to generate successive TB values independently. That formulation is not entirely faithful because of the bunching of multiple ATCRBS fruit, which we understand to be caused by the mechanism in which a single interrogation can elicit multiple replies. This mechanism is illustrated in a previous working paper (1090-WP-12-14). The approach used here will correctly generate a pair of fruit closely spaced, but after one such small value of TB, the next value of TB will be independently generated. To check for the validity of the non-Poisson fruit model generated using this approach, we applied the histogram analysis to the resulting fruit. The resulting histogram has a bell shape, as expected, and departs from the Poisson distribution, as expected. It has a greater variance than the mean value, in the ratio

$$\text{variance} / \text{mean} = 1.6$$

This value is somewhat less than the values we have consistently observed in analyzing airborne fruit measurements.

Recognizing that this analysis is not entirely faithful, we nevertheless believe that it is useful in arriving at the main conclusion, which is that the non-Poisson timing behavior of ATCRBS fruit does not have a significant effect on Extended Squitter reception probability.

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Reference 1. "1090 MHz Extended Squitter Assessment Report," Prepared by FAA and EUROCONTROL Experimental Centre, June 2002.