1090-WP-14-05
25 September 2002

RTCA Special Committee 186, Working Group 3

ADS-B 1090 MOPS, Revision A

Meeting #14

Enhanced Preamble Detection, New Material for Appendix I

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SUMMARY
At the last meeting, 1090-WP-13-13 proposed changes to Appendix I to the Enhanced Preamble Detection process based on a combination of the techniques developed by Lincoln Labs and the Tech Center. The proposed changes were pending analysis of additional preamble tests not yet included in the Tech Center version. This paper presents data showing improved performance due to the additional preamble tests that are now incorporated into the Tech Center baseline enhanced decoder and provides a re-issue of the new material for Appendix I (that also includes a corrected Figure B).

Introduction

At Meeting #13 Working Paper 1090-WP-13-13 was presented proposing new material for Appendix I. The new material was a description of an enhanced preamble detection technique based on a combination of the techniques developed at the Technical Center and Lincoln Labs. The description included 1, 3.5, and 4.5 Microsecond Tests and a Consistent Power Test developed by Lincoln Labs that were not implemented in the Technical Center technique at that time. These tests have since been included in the Technical Center technique. This Working Paper contains a comparison of the performance of the enhanced decoder both prior to and after the inclusion of these additional preamble tests.

Test Data

A subset of the enhanced decoder test procedures was run to determine the effect of the additional preamble tests on decoder performance. The technique utilized the indicated preamble detection process along with the baseline bit and confidence decoding method. Figure 1 shows the performance comparison with the Combined Preamble and Data Block Tests with 5 Mode A/C Fruit. There is a slight increase in performance with the additional preamble tests.

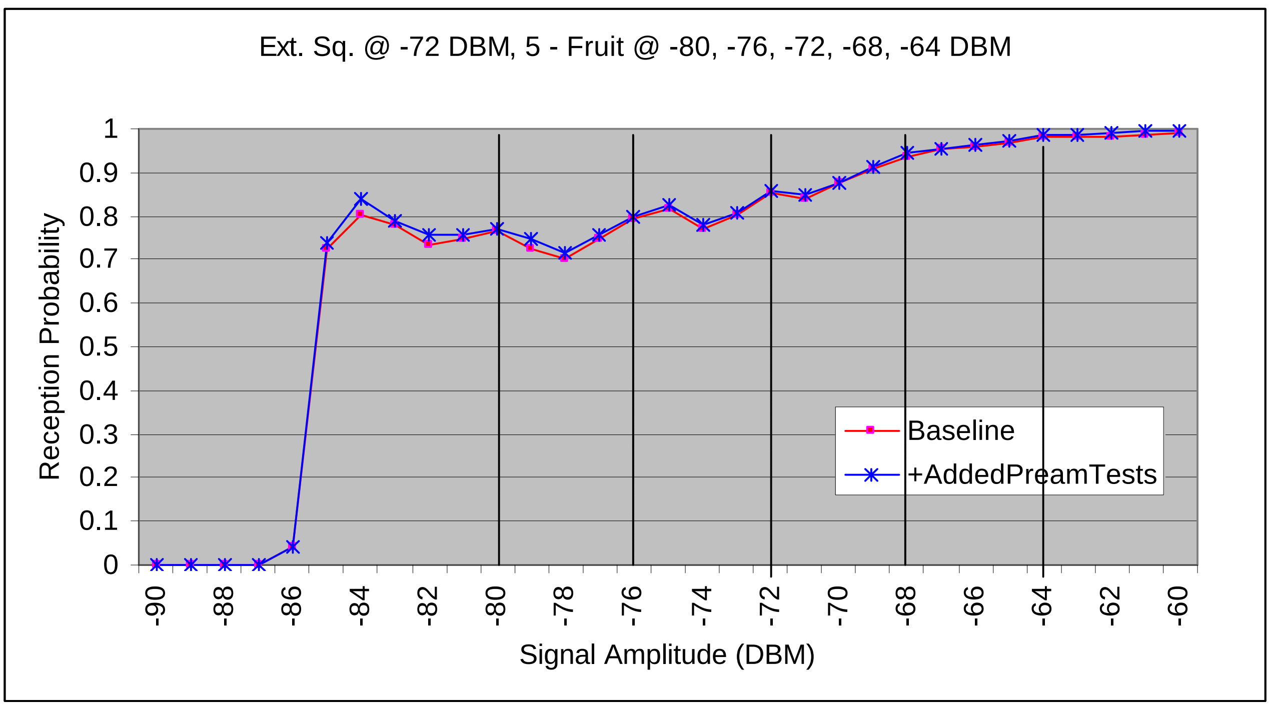

Figure 1. Combined Preamble and Data Block Tests with 5 Mode A/C Fruit

Figure 2 shows a performance comparison with the Re-triggering test with Varying Position Mode S Fruit. The overall performance with the additional preamble tests is better and the decoder is now able to fully recover when the extended squitter is 12 dB or more stronger than the interfering signal.

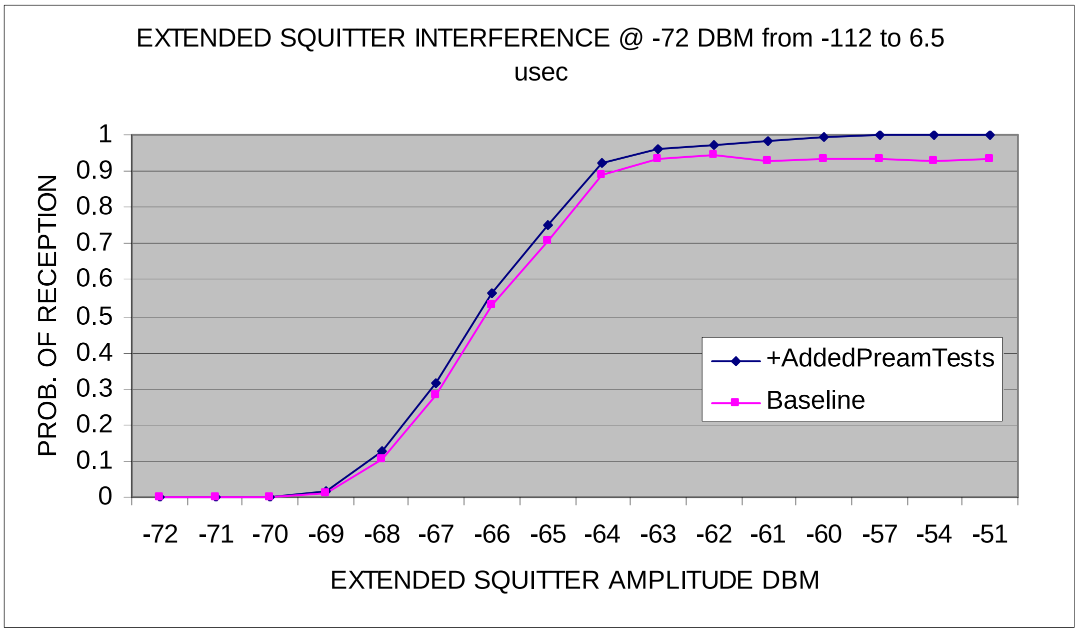

Figure 2. Re-Triggering Test with Varying Position Mode S Fruit

A 6-minute data sample recorded in Frankfurt on May 24, 2000 was processed with the additional preamble tests as well. This is the same data sample and aircraft extended squitter reception that has been used in previous analysis of enhanced decoding. The reception rate for this aircraft during this time period was significantly poorer than typical for the given range. Figure 3 shows a comparison of the reception rate for the six-minute time period for both with and without the additional preamble tests. The overall average reception probability with the added preamble tests is 39.4% and without them is 36.1%. Figure 4 shows the probability of reception versus range with the added preamble tests.

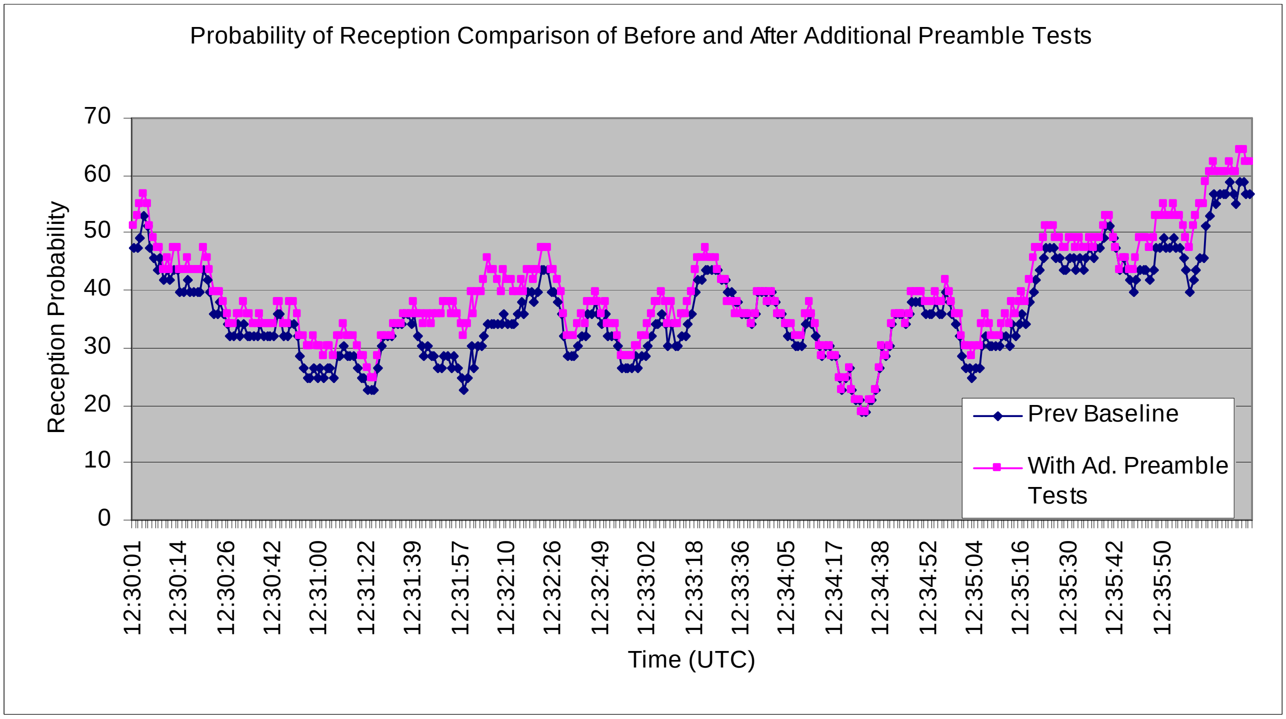

Figure 3. Probability of Reception of Extended Squitters from Aircraft 3CCE6E in Frankfurt, May 24, 2000

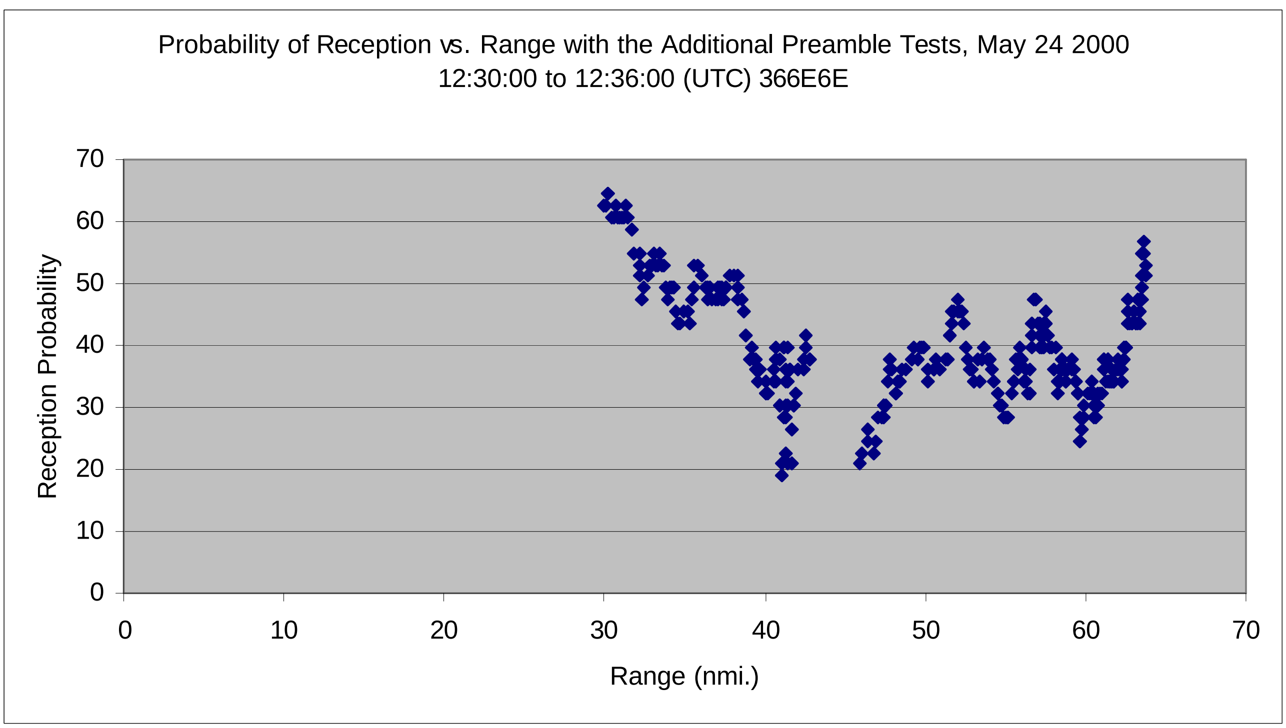

Figure 4. Probability of Reception of Extended Squitters vs. Range from Aircraft 3CCE6E, Frankfurt May 24, 2000

Draft Material for Appendix I

The following text contains the proposed change to Appendix I that was originally drafted in 1090-WP-13-13:

Revised Outline. We have simplified the outline to eliminate redundant material. The overall outline of Appendix I seems quite reasonable. The enhanced techniques are described in part 4, which is divided into three subparts,

4.1 Preamble
4.2 Bits and confidence
4.3 Error detection and correction,

However, within §4.1, the current outline seems excessively complex. We are proposing a simpler structure, having just one level of subheadings. The revised outline is as follows.

1. Purpose and Scope
2. Background
3. Current Squitter Reception Techniques
4. Enhanced Squitter Reception Techniques
    - 4.1 Enhanced Preamble Detection
        - 4.1.1 Log Video Samples
        - 4.1.2 Threshold
        - 4.1.3 Valid Pulse Position
        - 4.1.4 Leading Edge
        - 4.1.5 Initial Detection of a 4-Pulse Preamble
        - 4.1.6 Arrival Time
        - 4.1.7 Reference Level Generation
        - 4.1.8 Overlapping Signals and Retriggering
            - 1-Microsecond Test
            - 3.5 Microsecond Test
            - 4.5 Microsecond Test
        - 4.1.9 Consistent Power Test
        - 4.1.10 DF Validation
        - 4.1.11 Retriggering
        - 4.1.12 Preamble Detection Summary
    - 4.2 Enhanced Bit and Confidence Declaration
    - 4.3 Enhanced Error Detection and Correction Techniques
5. Improved Reception Performance in a High Fruit Environment
6. Summary

New draft. The following material is intended to replace all of the §4.1 material.

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4.1 Enhanced Preamble Detection

Preamble detection identifies the beginning of an Extended Squitter reception. The process has two outputs: (1) the start time of the signal and (2) the received power level of this signal. This process includes validation that uses the receptions during the first 5 bits in the data block and several other validation tests. Following is a description of a particular enhanced preamble detection technique that has been used successfully in achieving the performance required in this MOPS.

4.1.1 Log Video Samples

The preamble detection process described here operates on data in the form of samples of the log video received waveform. Specifically, the sample rate is 10 samples per microsecond, although other sample rates, including 8 samples per microsecond, have been found to be effective.

4.1.2 Threshold

The preamble detection process includes a threshold power level used to discard very weak receptions. Typical value = -88 dBm (referred to the antenna) for an A3 receiver. The Minimum Triggering Level (MTL), which is the point of 90 percent receptions in the absence of interference, is typically about 4 dB higher than the threshold.

4.1.3 Valid Pulse Position

A sample that is above threshold and also is followed consecutively by N or more samples above threshold is defined to be a "Valid Pulse Position." If the sample rate is 10 per microsecond, N = 3. This definition has the effect of defining a pulse as an event in which at least 4 consecutive samples are above threshold. For other sample rates, N is adjusted so that a pulse is declared when the signal is above threshold for more than 0.3 microseconds.

4.1.4 Leading Edge

A Leading Edge is declared for a particular sample if it is a Valid Pulse Position and also has substantial slope in the interval before this sample and less than substantial slope in the next interval. Substantial slope is defined by the power change between one sample and the next. The slope threshold is 48 dB per microsecond (applicable to receiver bandwidth of approximately 8 MHz). Therefore if the sample rate is 10 samples per microsecond, the threshold is 4.8 dB.

4.1.5 Initial Detection of a 4-Pulse Preamble

The preamble detection process begins when four pulses have been detected, having the spacing of the Mode S preamble. The detection criterion is:

- Finding four pulses having timing of 0 - 1.0 - 3.5 - 4.5 microsecond
- Two or more of these must be Leading Edges.
- The others can be Valid Pulse Positions
- Sample tolerance can be plus or minus 1 (but not both)

Note that the power levels in the four pulses need not agree. Note also that trailing edges are not used.

4.1.6 Arrival Time

The signal arrival time is initially estimated to be the leading edge of the first of these four pulses. Subsequently this is adjusted by +1 or -1 sample if two or more of the other three pulse have leading edges with that timing.

4.1.7 Reference Level Generation

A Reference Power Level is generated during preamble detection for use in re-triggering and during demodulation of the data block. Step 1 is to identify a set of samples to use. Among the four preamble pulses, those whose leading edges agree with the preamble timing are used; samples from the other pulses are not used. Next, for each pulse used, select the M samples after the leading edge sample. If the sample rate is 10 per microsecond, M = 3. For other sample rates, the value of M is equal to the value of N defined in I.4.1.3.

Step 2 is an algorithm to generate the Reference Level from these samples. For each sample, compute the number of other samples that are within 2 dB. Then find the maximum of these counts. If the maximum count is unique, then the sample used to form that count is taken to be the Reference Level.

Otherwise, when there are two or more samples whose counts are maximum and equal, discard any samples whose counts are less than this maximum. For the remaining samples, find the minimum power and then discard any samples that are more than 2 dB stronger than that minimum. Compute the average of the remaining samples. This is taken to be the Reference Level for the preamble.

4.1.8 Overlapping Signals and Retriggering

The preamble detection process is capable of processing multiple overlapped preambles, but the data block processing, which is more extensive, can only accept one signal at a time. For this reason, a re-triggering function is included. This function will reject certain preamble detections when a subsequent stronger signal is received.

One step in the re-triggering process checks for overlap by later Mode S signals having certain specific timing offsets. For example, if the subsequent signal is 1 microsecond later, then two of the preamble pulses in the later signal coincide with preamble pulses in the original signal, which can cause a problem if the later signal is stronger. The potential problem is that the stronger pulses can cause the power estimate for the first signal to be too high, and therefore prevent re-triggering. This type of problem can also occur if the timing difference is 3.5 or 4.5 microseconds. Figure A illustrates the 1 microsecond overlap that motivates this test.

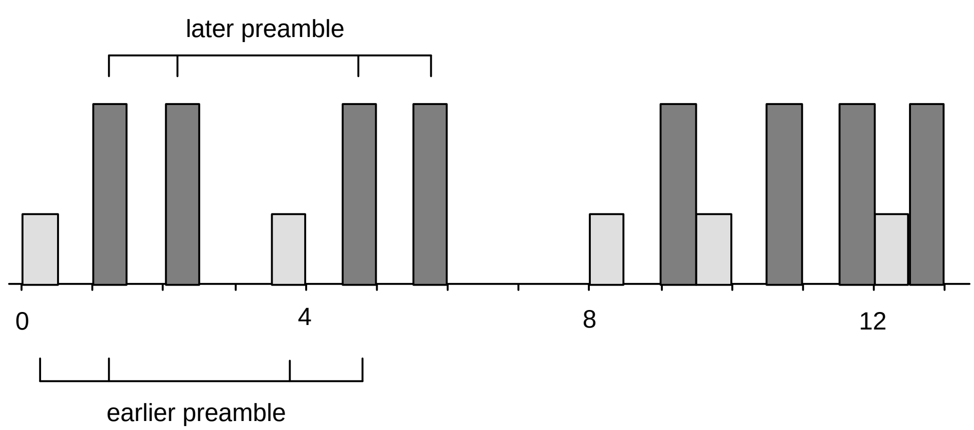

Figure A. Overlap of a weak signal by a later and stronger signal.

1-Microsecond Test. To counter this potential problem, the next step after preamble detection is to check for excessive power in pulse positions 1.0, 2.0, 4.5, and 5.5 microseconds after the start. For each of these pulse positions, one sample is used to estimate the power of a pulse at that time. Letting T = 0 denote the time one sample after the leading edge time of the first preamble pulse, then the four pulses are taken to be the samples at times T = 1.0, 2.0, 4.5, and 5.5 microseconds. From these four power measurements, the minimum is used to compare against the maximum of the samples at T = 0 and 3.5 microseconds. If this difference indicates that the preamble under consideration is -3 dB or weaker relative to the other four samples, then this preamble is rejected.

3.5-microsecond test. A similar test is performed to protect against overlap by a stronger signal 3.5 microseconds later. The minimum power in samples at T = 3.5, 4.5, 7.0, and 8.0 is compared against the maximum of the samples at T = 0 and 1.0 microseconds. If this difference indicates that the preamble under consideration is -3 dB or weaker relative to the other four samples, then this preamble is rejected.

4.5-microsecond test. A similar test is performed to protect against overlap by a stronger signal 4.5 microseconds later. The minimum power in samples at T = 4.5, 5.5, 8.0, and 9.0 microseconds is compared against the maximum of the samples at T = 0, 1.0, and 3.5 microseconds. If this difference indicates that the preamble under consideration is -3 dB or weaker relative to the other four samples, then this preamble is rejected.

4.1.9 Consistent Power Test

Another test is applied to validate the preamble. This test asks whether at least two of the four preamble pulses agree in power level with the Reference Level to within +/-3 dB. If not, this preamble is rejected.

4.1.10 DF Validation

An additional validation is made using the first five bits in the data block. Each of the five bits is considered to consist of two chips, each of duration 0.5 microseconds. Pulse detection is carried out for the 10 chips as follows. For a particular chip, a pulse is detected if a Valid Pulse Position is found at the leading edge time for this chip or within +/-1 sample of the leading edge time. The preamble is then validated if, for each of these five bits, a pulse is detected either in the first chip or in the second chip or both and the peak amplitude of the pulse is equal to 6 dB below the preamble reference level or greater. Otherwise the preamble is rejected. The peak amplitude is determined by using the highest amplitude sample of the M samples that comprise the pulse (where M = N + 1 for N as defined in I.4.1.2).

4.1.11 Re-triggering

After a preamble is detected, the preamble detection process continues to be applied searching for later preambles. All of the steps described above are applied even when detected preambles are overlapped. If a particular preamble detection has survived these tests, its reference level and the amplitude of each of the five data pulses during DF validation is now compared against any earlier signal currently being processed. If the new signal is stronger by 3 dB, then the earlier signal is rejected, so that data block demodulation of the new signal can proceed. Otherwise (if an earlier signal is being processed and the new signal is not stronger by 3 dB), the new signal is rejected, so that the earlier signal processing can continue.

4.1.12 Preamble Detection Summary

Figure B summarizes the preamble detection process.

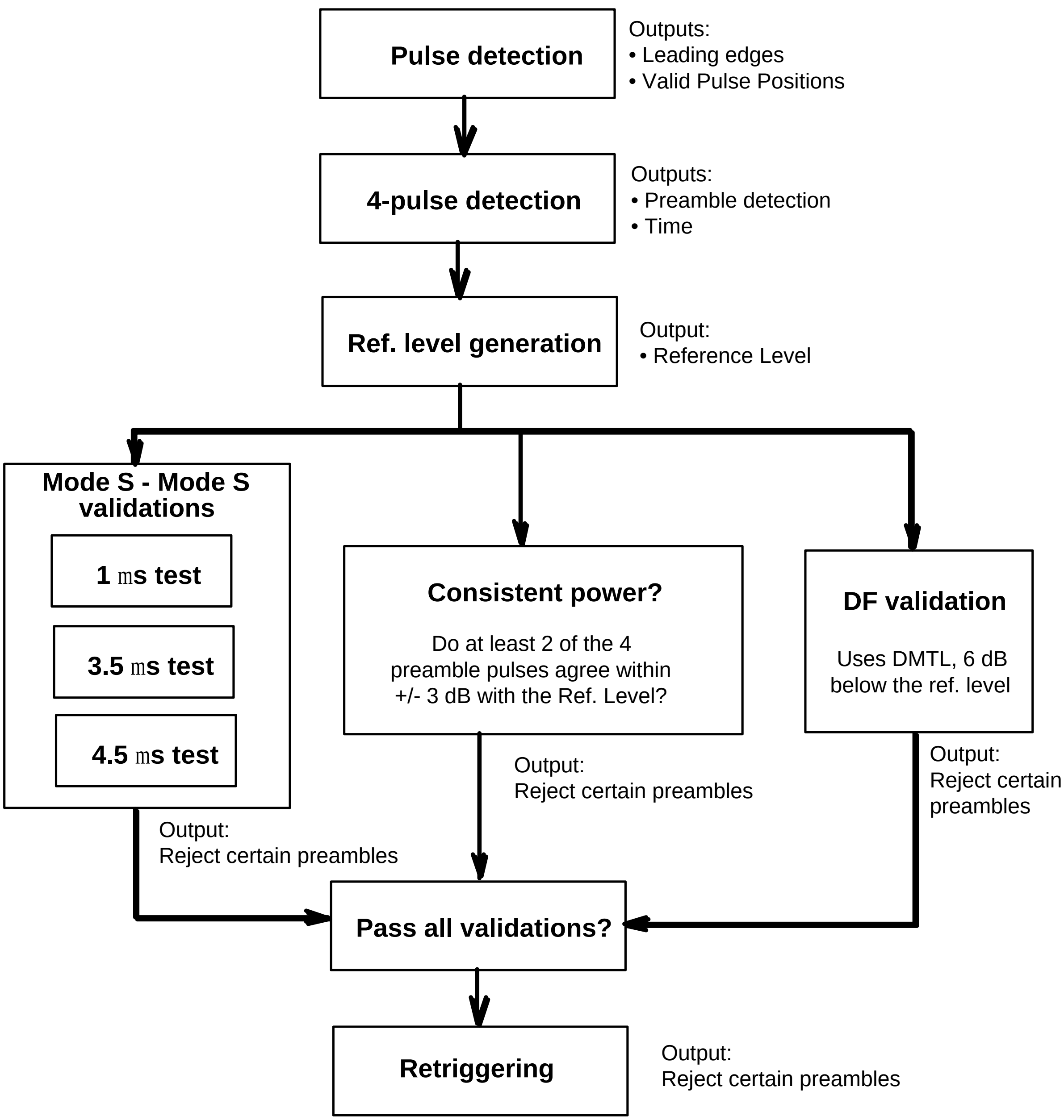

Figure B. Overview of Extended Squitter Preamble Detection.

4.2 Enhanced Bit and Confidence Declaration

4.3 Enhanced Error Detection and Correction Techniques