IMPROVEMENT ON ALGORITHM OF CONFIDENCE DECLARATION OF MODE S SECOND SURVEILLANCE RADAR

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Abstract  Mode S Second Surveillance Radar (SSR) is very important means for Air Traffic Control (ATC) now and future, all the responding data which the radar receives need parity processing. Bit and confidence declaration is an vital step before error detection and error correction. Based on the commonly used baseline multi-sample algorithm, different conditions are presented and analyzed, the conditions under which error happens are pointed out, and the algorithm in which two statistical variables are added to avoid false declaration. In addition, the moving average method is used to preprocess the sampled data, so as to reduce the influence of noise. The merits the baseline multi-sample technique owes are preserved, and the added computation is small. The declaration veracity is improved, and consequently makes error detection and error correction be facilitated successfully.

Key words  Mode S; Second Surveillance Radar (SSR); Confidence; Baseline multi-sample

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I. Introduction

Mode S Second Surveillance Radar (SSR) interrogates the planes one by one, by adding the plane address in the interrogating signal only the plane whose address code is consistent with the received address code will respond[1–3]. The selective interrogator can overcome radically the garbling phenomenon of ordinary SSR. For mode S SSR it is an important step to decode the bits, detect and correct errors from the received signal[4], and the bit and confidence declaration is the base of successful error detection and correction. There are many techniques to determine bit and confidence such as center amplitude technique, baseline multi-sample technique and multi-sample technique with table lookup[5], and frequency domain algorithm[6]. Among them the baseline multi-sample technique[7] is used widely because of the brief process, less Random-Access Memory (RAM) occupation and objective result. In this letter the baseline multi-sample technique is analyzed and then improved.

II. Confidence Declaration Algorithm Introduction

The reply data of Mode S SSR is coded by Pulse Position Modulation (PPM). For each bit position which lasts 1 μs, there is a pulse and a no-pulse period, each duration 0.5 μs, with a binary 1 represented by a pulse followed by a no-pulse and a binary 0 by a no-pulse followed by a pulse. As is shown in Fig. 1.

![Pulse position modulation sketch](image)

When decoding each information bit from the reply data, it is necessary to estimate the bit confidence which makes for the consequent error detection and correction. The SSR with Mode S and without Mode S is different in bit and confidence declaration[8,9]. The simplest decoding technique is...
center amplitude method by comparing which chip sample is greater, if Chip1 is greater than Chip0 it means one, and if not it means zero. The confidence determined by the level of the weaker chip, if the signal level is low, it shows that no interference exists and thus the bit confidence is high. This method can eliminate the effects of weak False Replies Unsynchronized to Interrogator Transmission (FRUITS). Though it is simple it does not make the most of the sampled data.

The more complicated techniques make full use of the multi-sampled data. One of them is the table lookup technique. The reply data is divided into four kinds according to their amplitudes. The input of the table is the amplitude distribution of the 10 sampled data, the content of the table is bit value and confidence value. So two 1-bit wide tables are needed, with each $4^{10} = 1048576$ (1 Mbit). A lot of storage space is needed to implement this method.

The baseline multi-sample bit and confidence declaration technique makes use of all 10 samples to determine the bit and confidence values and it occupies little storage space. The technique is as follows.

**Step 1** The first step is to establish an amplitude window that include samples within $\pm 3$ dB of the preamble reference level and a minimum amplitude threshold set to 6 dB below the reference level. Samples that fall within the window are considered to match the preamble, and samples below the minimum amplitude threshold are considered to be lack of transmitted energy. The samples are categorized as follows.

- A: within the $\pm 3$ dB preamble window
- B: below threshold (6 dB or more below the preamble)

**Step 2** The second step is to count the number of samples in each chip that are of each category. Less weight is given to the samples near the transitional areas of each chip. To facilitate this, samples in the first and last of the chip count one time, and samples other than those at each end count twice. The four counters are summarized as follows.

- 1A: number of weighted samples in chip 1 of Type A
- 1B: number of weighted samples in chip 1 of Type B
- 0A: number of weighted samples in chip 0 of Type A
- 0B: number of weighted samples in chip 0 of Type B

Next, two equations using the above counts will produce two scores that indicate how well the sample pattern matches a transmitted 1 or a transmitted 0. The equations are as follows.

$$1S = 1A - 0A + 0B - 1B$$  \hspace{1cm} (1)

$$0S = 0A - 1A + 1B - 0B$$  \hspace{1cm} (2)

After computing the two equations we get two scores which are 1S and 0S. The higher score determines the bit value, which means: if $1S > 0S$ then the bit value is 1, if $0S > 1S$ or $0S = 1S$ then the bit value is 0. If the difference $|\Delta S| > 3$ or more the bit is high confidence. If sampling rate changes, the threshold number 3 will change accordingly.

**III. Analysis of Baseline Multi-sample Technique**

We now apply baseline multi-sample technique to data with all kinds of interference. In Figs. 2~7, PL means Preamble Level, Chip1 denotes the amplitude of chip 1, Chip0 denotes the amplitude of chip 0.