# FRAME SYNCHRONIZATION IN DIGITAL BURST TELECOMMAND AT LOW SIGNAL TO NOISE RATIO

Alessandro Anzaloni
Centro Técnico Aeroespacial
Instituto Tecnológico de Aeronáutica
12.225 - S.J. dos Campos, SP, Brazil

José Carlos Juliano de Almeida
Centro Técnico Aeroespacial
Instituto de Atividades Espaciais
12.225 - S.J. dos Campos, SP, Brazil

## ABSTRACT

Frame synchronization was extensively studied usually supposing that the bit pattern to acquire frame synchronization was imbeded in sequences of random bits. In this paper, the determination of a bit pattern for frame synchronization in digital burst telecommand at low signal to noise ratio is investigated, considering the a priori knowledgement of a bit pattern for bit synchronization and the format of the frame. The a priori knowledgement of a bit pattern for bit synchronization is used to find a bit sequence that minimize the false probability to acquire frame synchronization. A simple strategy using the aperture technique is stablished. An egineering model is used to find experimentally the mean probability of true synchronization after one burst. This initial research to find a bit pattern for frame synchronization presented good results.

## INTRODUCTION

In this paper we present our first results on frame synchronization in digital burst telecommand at low signal to noise ratio.

At low signal to noise ratio bit synchronizers, like the Early-Late Synchronizer, [1], are necessary and, as it is well known, this type of synchronizers need a long and well defined bit pattern to acquire and maitain bit synchronization (BPBS).

Due to this the size of such BPBS in our frame is greather than its own telecommand word. Therefore, the probability of acquiring false frame synchronization in the region of BPBS must be considered and minimized.

Frame synchronization was extensively studied [2], [3], supposing that the bit pattern to acquire frame synchronization (BPFS) was imbeded in sequences of random bits.

One of the works [4] consider the existence of BPBS that precede the BPFS, but do not consider the a priori knowledgement of BPBS.

In this work the equations that represents the probability of false frame synchronization in the displacement regions are stablished, considering the a priori knowledgement of BPBS, and in this way minimizing this probabilities.

In the theoretical part os this work the expressions are found supposing that a digital correlator is used to detect the BPFS.

Considering that the best BPBS for the Early-Late Synchronizer (when the input is a PCM/NRZ signal) is an alternating sequence of 1's and 0's equations that appear in [4] are modified, as well as new equations are found.

Using this equations and a given criterion, the BPFS is found from a well defined frame.

In the experimental part, a simple strategy to acquire frame synchronization using the aperture technique [4] is shown.

A prototype implementing such a strategy is used to measure the mean probability to acquire frame synchronization (to a given signal to noise ratio) after one burst.

Finally, in the conclusions, the main results are discussed and further research is addressed.

**THEORETICAL PART**

Figure 1 shows the frame structure that is used in the analysis. Where:

m = number of bit in the BPBS (alternating $\underline{1}$ and $\underline{0}$)
n = lenght of the BPFS
N = lenght of the frame in bits
RB = number of bits in the telecommand word that are considered random.

Where, $$m > n + RB \tag{1}$$

Considering that the frame of Figure 1 is constantly shifted through a digital correlator, the following probabilities of false frame synchronization in the displacement regions, can be defined($^{*}$):

(i) Only random bits are in the correlator.

---

$^{*}$ The development of formulas that are shown here is similar to that used by [4]

The probability of at least one false detection per frame in the random bits is:

$$H_\beta = 1 - (1 - F)^\beta \quad , \quad \beta = RB - n + 1 \tag{2}$$

and

$$F = \frac{1}{2^n} \sum_{i=0}^{\varepsilon} \binom{n}{i} \tag{3}$$

Where:

$F$ = false detection probability, if only random bits are in the detector

$\varepsilon$ = number of errors allowed b the correlator

$\binom{n}{i}$ = binomial coefficient

(ii) Bits of BPFS and random bits are in the correlate.

The false detection probability in the displacement region is given by:

$$H = \left(\frac{1}{2}\right)^b \cdot \sum_{i=E_b - \varepsilon}^{E_b} \binom{E_b}{i} p^i \cdot q^{E_b - i} \cdot \sum_{j=0}^{\varepsilon - E_b + i} \binom{n - E_b - b}{j} \cdot p^j q^{n E_b - b - j} \cdot$$
$$\cdot \sum_{K = E_b + b - \varepsilon - i + j}^{b} \binom{b}{k} \tag{4}$$

Where:

p = bit error probability
q = 1 - p
$E_b$ = number of erroneous bits in the BPFS in such way that error due to the displacement <u>b</u>
    is zero
b = displacement of BPFS in the detector

(iii) Bits of BPFS and BPBS are in the correlator.

The false detection probability in this displacement position is given by:

$$H' = \sum_{i=E'_b-\varepsilon}^{E'_b} \binom{E'_b}{i} \cdot p^i \cdot q^{E'_b-i} \cdot \sum_{j=0}^{\varepsilon-E'_b} \binom{n-E'_b}{j} \cdot$$

$$\cdot p^j \cdot q^{n-E'_b-j}$$

(5)

Where:

$E'_b$ = number of errors in the BPFS and BPBS in such way that the error due to the displacement b is zero

Observe that this equation was written considering equation (1).

(iIV) Only bits of BPBS are in the correlator.

The calculation of this false detection probability was done supposing an alternating sequence of 1's and 0's for the BPBS. This sequence have the characteristic of generating only two events that can give false detection. The corresponding probabilities of false detection are SW0 and SW1.

The general expression is given by:

$$SWb = \sum_{i=S_b-\varepsilon}^{S_b} \binom{S_b}{i} \cdot p^i \cdot q^{S_b-i} \cdot \sum_{j=0}^{\varepsilon-E_b+i} \binom{n-S_b}{j} \cdot p^i \cdot q^{n-S_b-j}$$

(6)

Where:

$S_b$ = number of bit errors in BPBS such that the error due to the displacement b is zero.

If b is odd, SWb = SW1, if b is even, SWb = SW0.

From SW0 and SW1 the probability of false detection in one frame due to BPBS is:

$$H_N = 1 - (1 - SW0)^\xi \cdot (1 - SW1)^\lambda$$

(7)

Where: $\xi + \lambda = m - n + 1$

$\xi$ and $\lambda$ represent respectively the number of times that $\underline{b}$ is odd or even.

(iv) Bits of BPBS and random bits.

The false detection probability in this displacement region is given by:

$$RSb = \left(\frac{1}{2}\right)^b \cdot \sum_{i=R_b-\varepsilon}^{R_b} \binom{R_b}{i} \cdot p^i \cdot q^{R_b - i} \cdot \sum_{j=0}^{\varepsilon - R_b + i} \binom{n - R_b - b}{j} \cdot$$

$$\cdot p^j \cdot q^{n - R_b - j} \cdot \sum_{K = R_b + b - \varepsilon - i + j}^{b} \binom{b}{k}$$

(8)

Where:

$R_b$ = number of error in the BPBS in such way that error due to the displacement $\underline{b}$ is zero
b = number of random bits in the correlator

The criterion used to find the BPSF was the exaustive search of bit pattern with all probabilities of false detection lower than F and with a high density of transitions. The high density transmissions is required to mantain the performance of the Early-Late bit Synchronizer.

A program implementing such criteria and using the equations shown before, was written.

In Table I, it is shown the BPSF and the probablities of false detection, that were found with the following system parameters:

m = 150
n = 23
RB= 39
p = 0.5 x $10^{-4}$
S/N= 9 dB

The 39 random bits represent a telecommand code word that belong to a modified Hamming code (32,7) with the capability of correcting on error and detecting two errors.

The probabilities of false detection RSb, H, H' are function of the displacement $\underline{b}$, and in the Table I only the maximum and minimum value of such probabilities are shown.

From Table I, can be seen that the BPFS have 15 transitions and very low probabilities of false synchronization.

The higher probability of false synchronization is due to the random bits.

## EXPERIMENTAL PART

In this part, a simple strategy to acquire frame synchronization in the burst mode, using the aperture technique it is shown. An engineering model of such strategy was implemented and the mean probability to acquire true frame synchronization after one burst was measured.

The strategy is as follows.

### Search Phase

This phase start with the first frame of the burst. This frame is constantly shifted through the digital correlator and generate at the output a pulse detection signal. This pulse detection signal initiate a counter that will generate another pulse after one frame period.

The search phase finishes when this latter pulse coincides with the pulse detection generated by the second frame in the burst.

### Verify Phase

In this phase it is verified if at least one of two coincidences between the digital correlator output and the counter happens. If this event is verified, the next frame in the burst will be decommutated and decoded.

From this strategy, follows that the burst will use five frames, where, four are used to acquire frame synchronization and one to detecte the telecommand (supposing that bit synchronization was already acquired).

In Table II, it is shown the mean probability of true frame synchronization (PTFS) after one burst as a function of the signal to noise ratio, when the BPFS that was found in the theoretical part was used.

From the results of Table II we can conclude that the PTFS has a sharp decrease with the signal to noise ratio. However at the signal to noise ratio of 9dB (used as a system parameter) the PTFS is almost one.

## CONCLUSIONS

From the results we can conclude that the equations of false frame synchronization derived, considering the structure of the frame and a priori knowledge of the BPBS, as well the criteria used, generate a useful BPFS that allows work with high probability of frame synchronization one burst.

However, more research must be conducted, comparing the performance of the system in terms of probability of the acceptance of the true telecommand word including bit synchronization, with the proposed pattern.

## REFERENCES

[1]    Anzaloni, A. et al, "A Simplified Analysis of an Early-Late Bit Synchronizer". European Conference on Telemetry 88, Garmish, West Germany.

[2]    Scholtz, R.A., "Frame Synchronization Techniques". IEEE Transactions on Communications, Vol. Com-28, No. 8, August 1980.

[3]    Maury, J.L. and Styles, F.J., "Development of Optimum Frame Synchronization Codes for Goddard Space Fligh Center PCM Telemetry Standards" Proc. 1965 Nat. Telemetering Conf. Los Angeles, CA, June 1964.

[4]    Schrempp, W. and Sekimoto, T., "Unique Word Detection in Digital Burst Communications". IEEE Transactions on Communication Technology, Vol. Com-16, No. 4, August 1968.
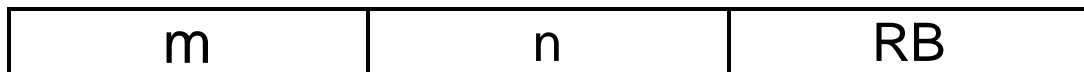
| m | n | RB |
|---|---|----|

FIGURE 1. FRAME STRUCTURE

## TABLE I. THE BPFS AND THE ASSOCIATE PROBABILITIES OF FALSE DETECTION

BPFS : 10101001010101010010000

F : $2.861E-6$

$H\beta_j$ : $0.48637E-04$

$H_N$ : 0

RSbMAX : $0.47731E-06$

RSbMIN : 0

H MAX : $0.3122E-16$

H MIN : 0.

H'MAX : $0.4773E-06$

H'MIN : 0.

## TABLE II. PTST AS FUNCTION OF THE SIGNAL TO NOISE RATIO

| S/N(dB) | PTFS |
|---------|------|
| 6 | 0.61 |
| 7 | 0.79 |
| 9 | 0.99 |