TFE25-462: Meeting 6

USRP-GNU Radio Integration and Schmidl and Cox Synchronization

Quentin Prieels

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USRP and GNU Radio

Schmidl and Cox Synchronization

Schmidl and Cox frame structure

- Require a specific frame structure.
- The *preamble* is will have good auto-correlation properties.
- It is composed of a single OFDM symbol with data (noise generated) only on even frequencies and zeros on odd frequencies.
- This makes the preamble *2-periodic* in time domain.

```
+----+--------+--------+----+-------------+----+-------------+----+-------------+
| CP |   A    |   A    | CP |   payload   | CP |   payload   | CP |   payload   |
+----+--------+--------+----+-------------+----+-------------+----+-------------+
|<------ Preamble ------>|<-------------------- N OFDM Symbols ------------------->|
```

Figure 1: Schmidl and Cox frame structure

Frame in simulation

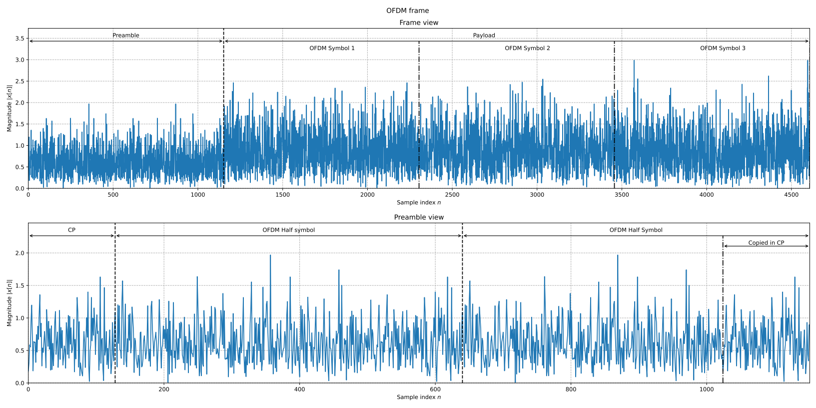


Figure 2: OFDM frame in time domain

Time metric $M(d)$ definition

In the original paper, Schmidl and Cox proposed to compute the time metric $M(d)$ as follows:

$$M(d) = \frac{|P(d)|^2}{(R(d))^2} \tag{1}$$

with:

$$P(d) = \sum_{m=0}^{L-1} r^*(d+m) \cdot r(d+m+L) \tag{2}$$

$$R(d) = \sum_{m=0}^{L-1} |r(d+m+L)|^2 \tag{3}$$

where $r(d)$ is the received signal and L is the length of the A symbol in the preamble. With K the number of subcarriers, $L = K/2$, an OFDM symbol in time domain is $K + CP$ samples long.

Time metric $M(d)$ computation

To compute those metrics, Schmidl and Cox proposed to use the following recursive formulas:

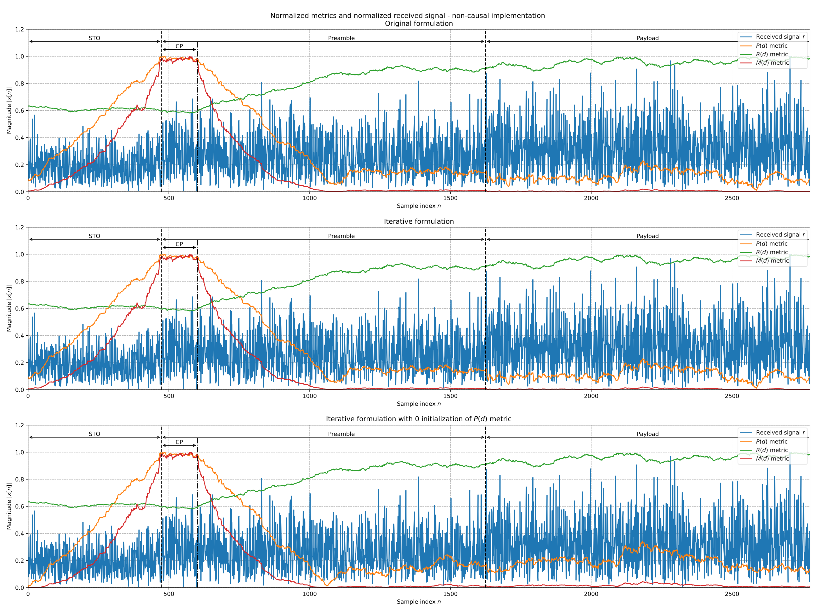
$$P(d+1) = P(d) + r^*(d+L) \cdot r(d+2L) - r^*(d) \cdot r(d+L) \quad (4)$$

$$R(d+1) = R(d) + |r(d+2L)|^2 - |r(d+L)|^2 \quad (5)$$

Remarks:

1. We still need to compute $P(0)$ and $R(0)$.
2. The system is not causal, still in needs to know the future.

Time metric $M(d)$ in simulation



Causal implementation of the time metric $M(d)$

To make the system causal, we delay the computation of $P(d)$ and $R(d)$ by $2L = K$ samples (length of the OFDM symbol without the cyclic prefix).

$$P(d+1) = P(d) + r^*(d-L) \cdot r(d) - r^*(d-2L) \cdot r(d-L) \tag{6}$$

$$R(d+1) = R(d) + |r(d)|^2 - |r(d-L)|^2 \tag{7}$$

where $R(0)$ is computed as:

$$R(d=0) = \sum_{m=-2L+1}^{L} |r(m)|^2 \tag{8}$$

Causal implementation using IIR filters

By introducing the $v(d)$ signal as $v(d) = r^*(d - L) \cdot r(d)$, we can rewrite the recursive formula as:

$$P(d+1) = P(d) + v(d) - v(d-L) \tag{9}$$

Causal implementation simulation

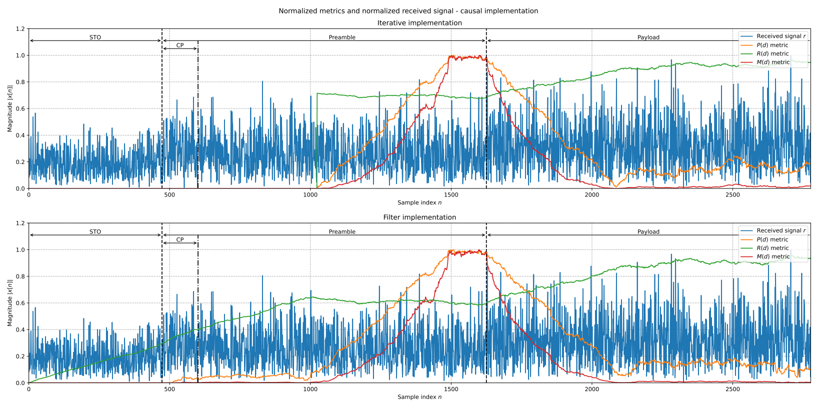


Figure 4: Time metric $M(d)$ computation with causal implementation

If we allow an initialization period

If we allow an initialization period of at least $2L$ samples, we can compute the time metric $M(d)$ with equation **??** and **??** without having to compute the "0" point.

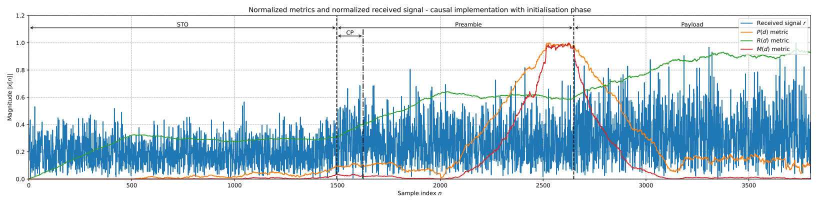


Figure 5: Time metric $M(d)$ computation with causal implementation and initialization period

Time metric $M(d)$ thresholding

The time metric $M(d)$ is thresholded to detect the beginning of the frame.

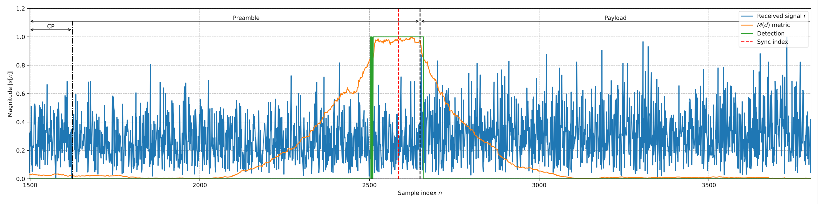


Figure 6: Time metric $M(d)$ thresholding

Remarks:

1. How to have a good threshold? (Here it is normalized to the maximum value, how to do it in practice?)
2. The plateau should be at least CP samples long. We can use this avoiding false positives.

Time metric $M(d)$ estimation

The value of the plateau depends on the noise power.

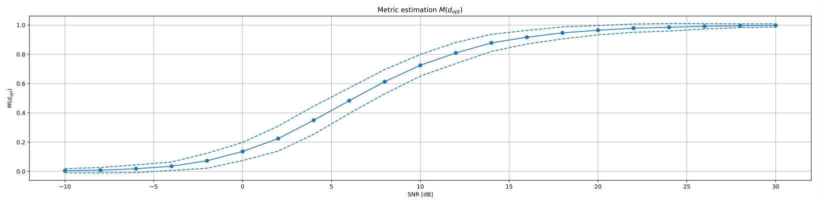


Figure 7: Time metric $M(d = d_{opt})$ for different SNRs values

where d_{opt} is the theoretical beginning of the plateau at *STO + CP + K - CP*.