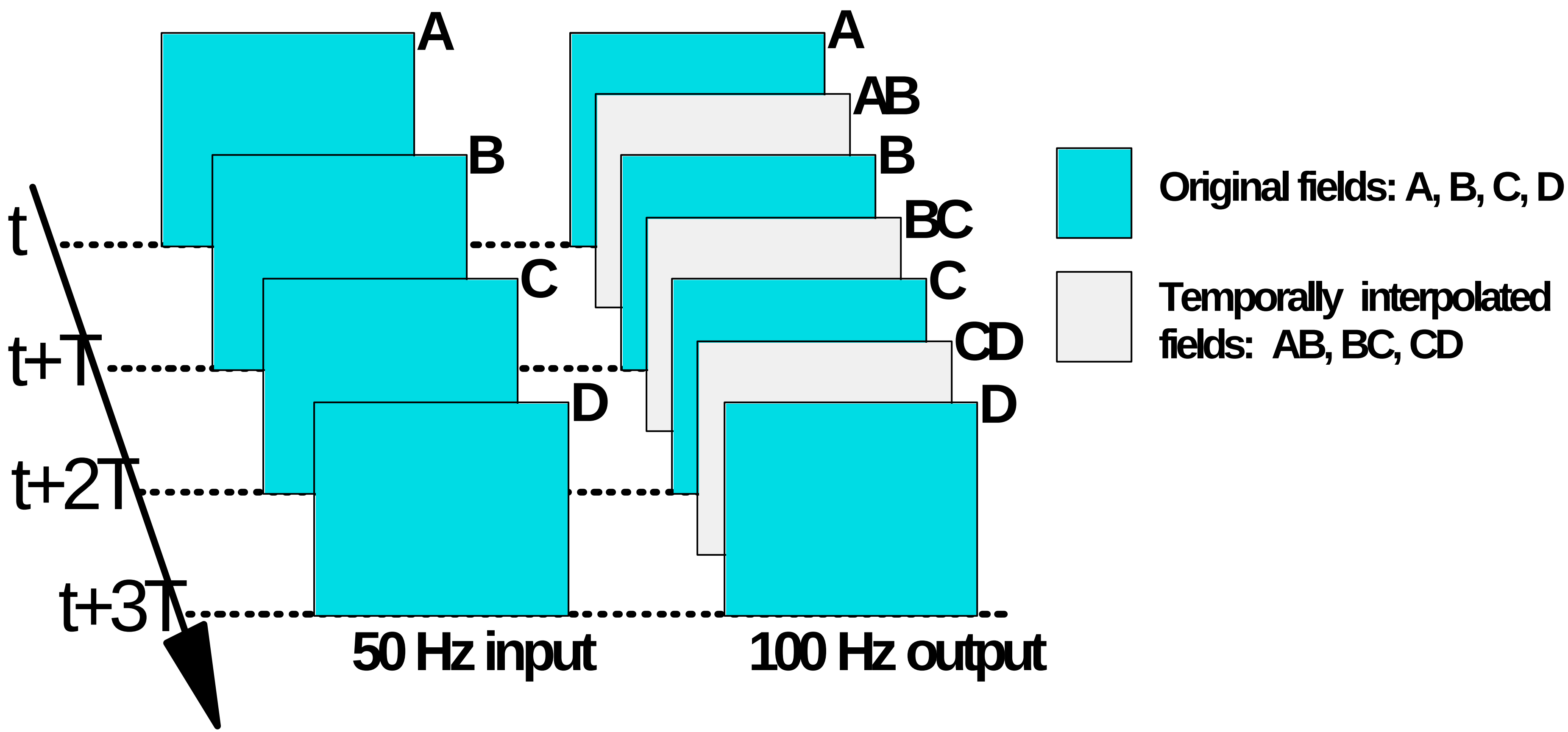
Scan rate conversion

Field Rate Doubling (FRD) and

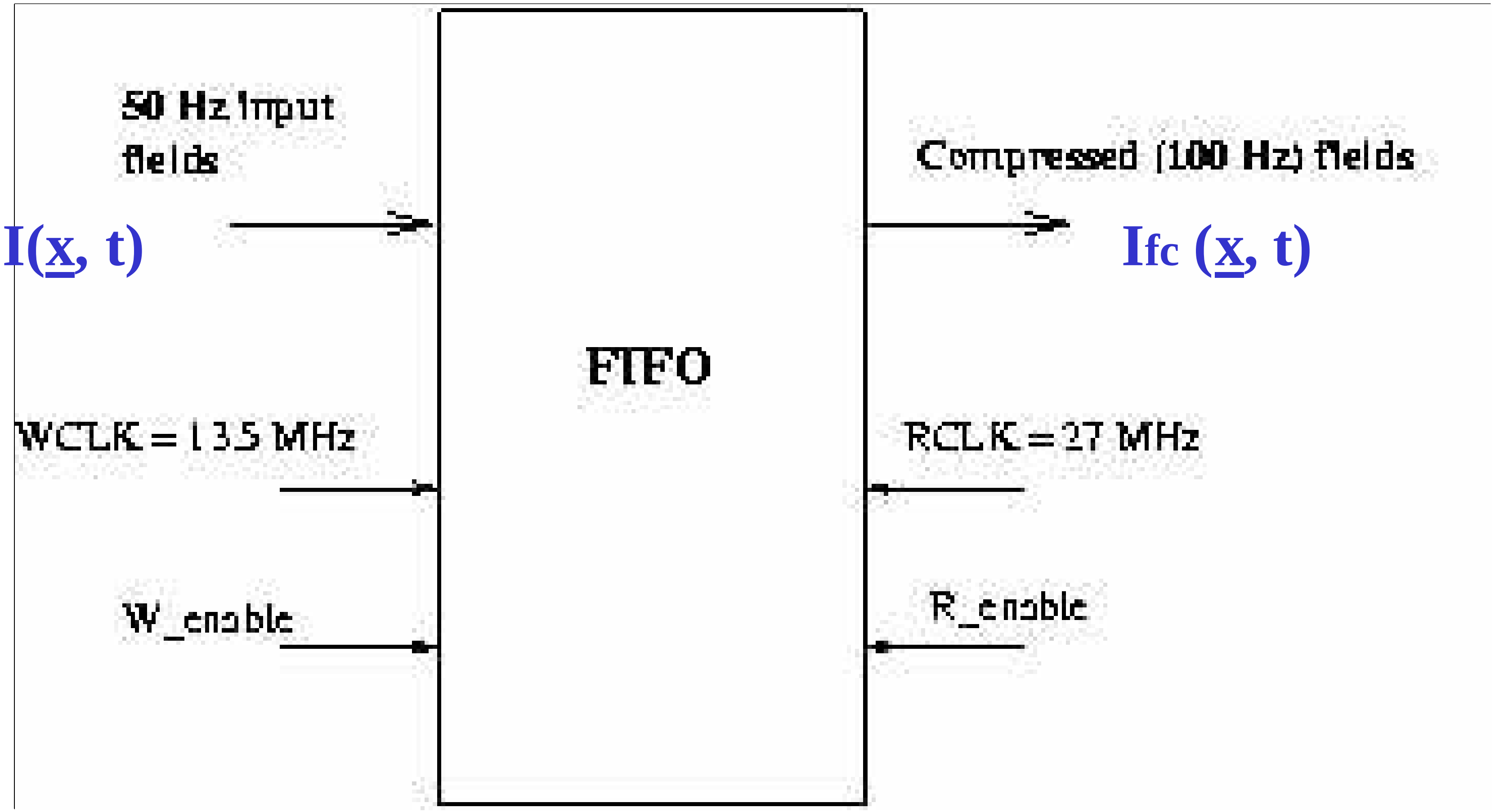
Line Rate Doubling (LRD or de-interlacing)

Field Rate Doubling



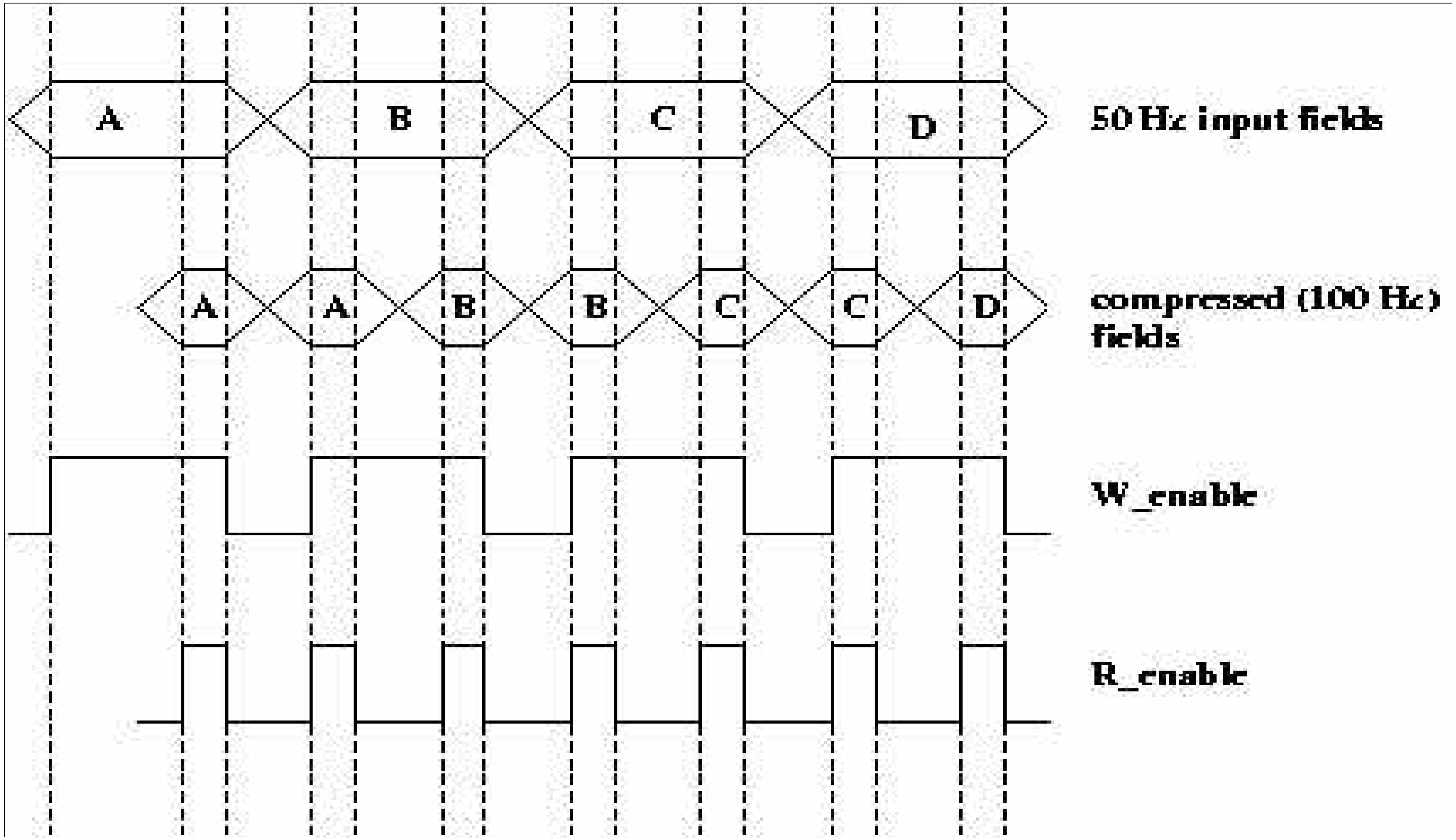
Two 100 Hz output fields are generated for each 50 Hz input field.

Time Compression (1)



A field memory device, with asynchronous write (WCLK) and read (RCLK) clocks, obtains the time compression.

Time Compression (2)

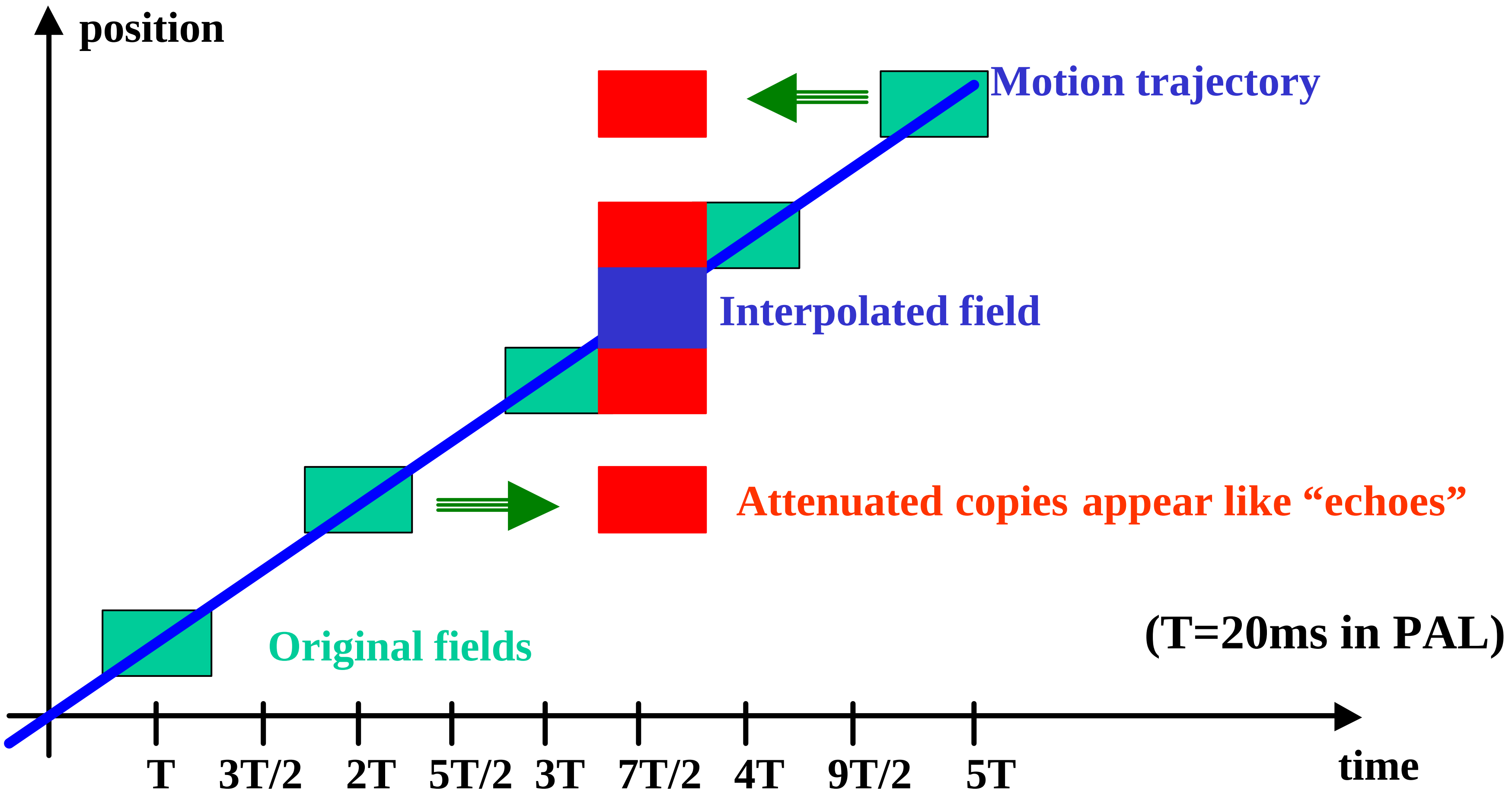


The processor works at two times the data rate. A theoretical time delay of 0.5 T is introduced by the time compression.

Disadvantages of classical SRC (1)

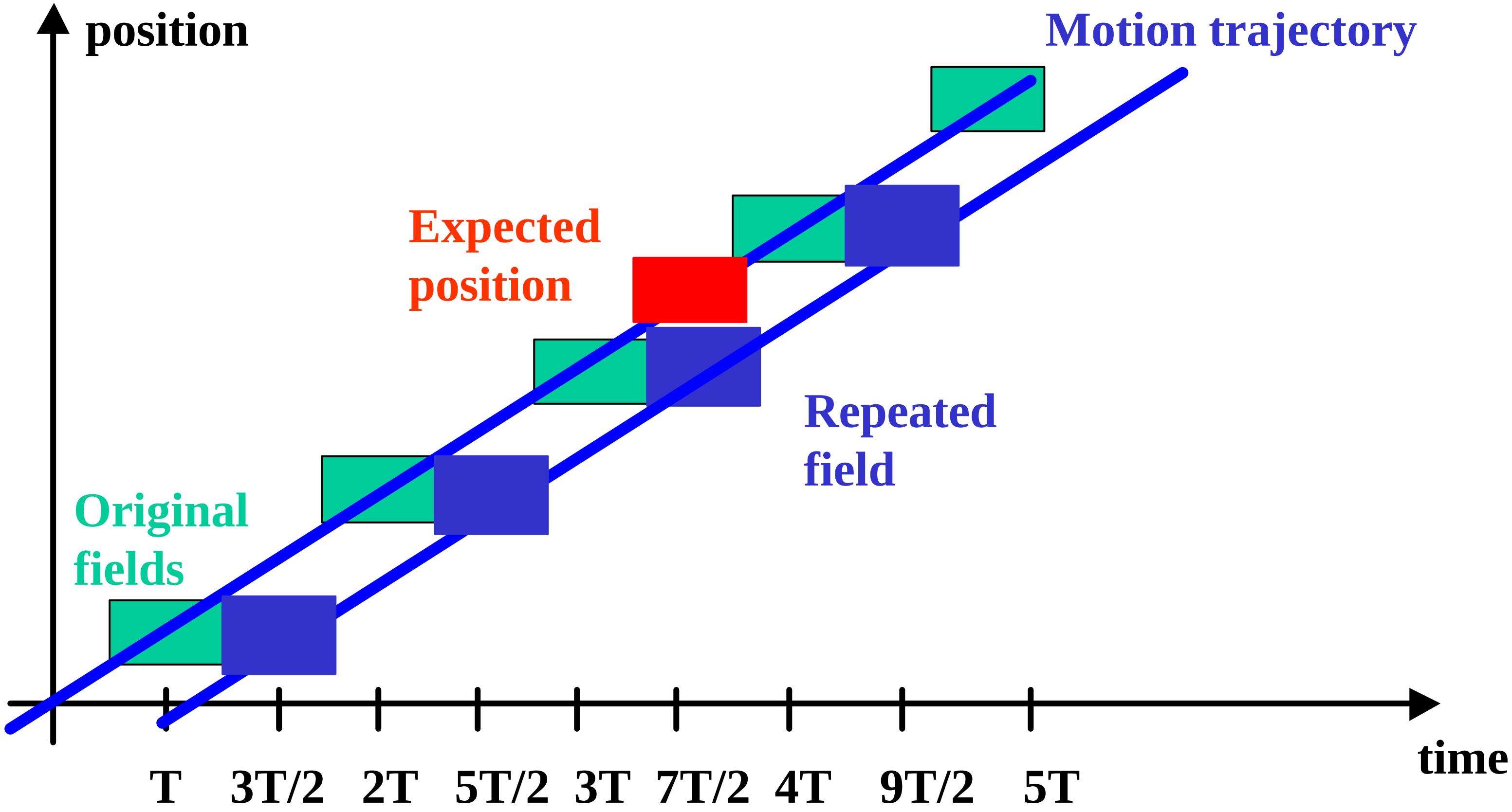
- **SRC temporal bandwidth limitation is unfeasible:**
  - **A picture with moving texture or edges, causes non zero temporal frequencies on the screen.**
  - **However, on the retina of the observer who tracks the moving object, the temporal frequencies are zero.**
  - **If now high temporal frequencies caused by the object movement were removed from video signal, then the object would seem blurred for the observer.**
- **The perception bandwidth of the eye for temporal frequencies does not apply to temporal frequencies in the video signal.**

Disadvantages of classical SRC (2)



Temporal interpolation for an object tracking observer

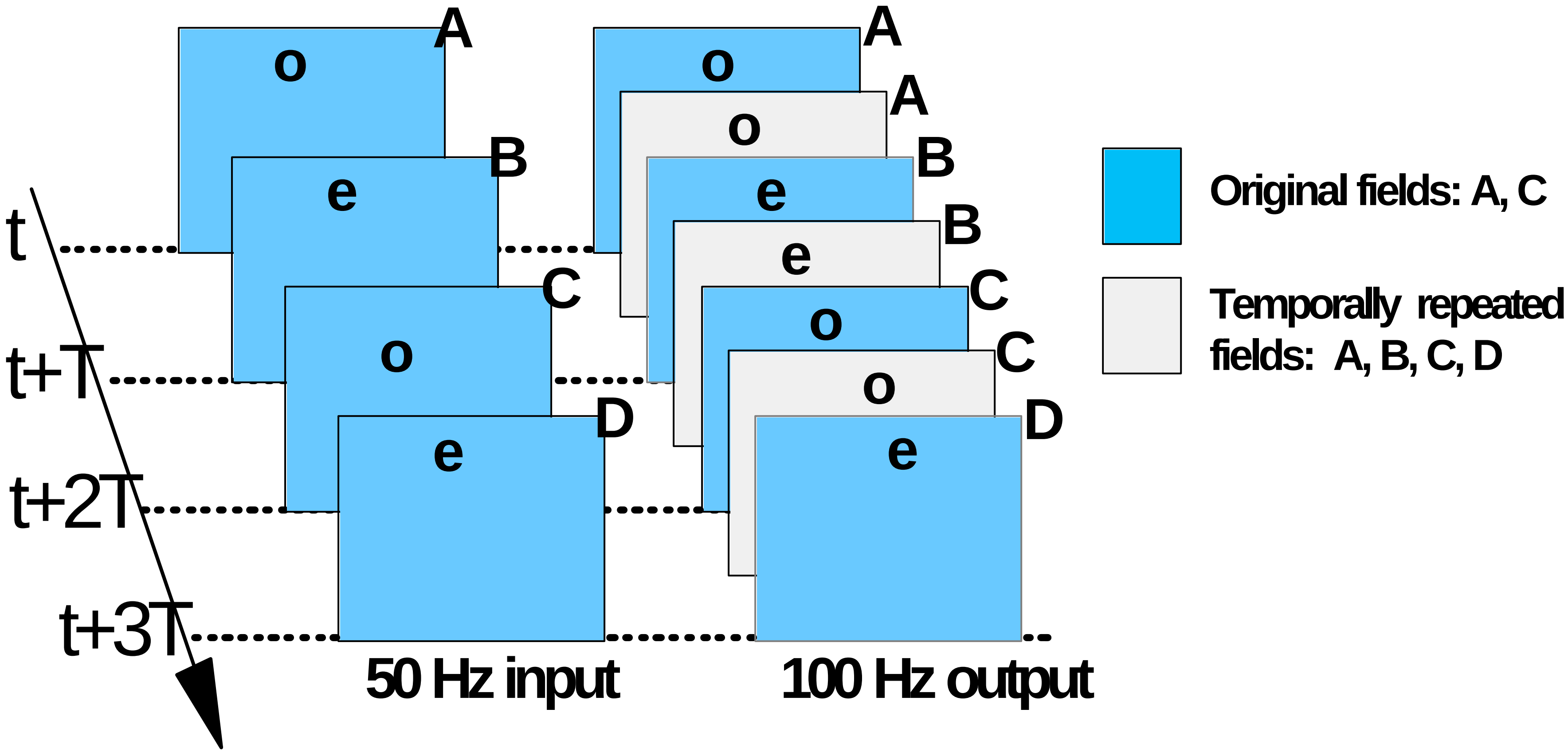
Field repetition (1)



output fields at $t = nT$: $I_{out}(\underline{x}, t) = I_{fc}(\underline{x}, t)$ **for** $t\%T=0$.

output fields at $t=(n+1/2)T$: $I_{out}(\underline{x}, t) = I_{fc}(\underline{x}, t-T/2)$ **for** $t\%T=T/2$.

Field repetition (2)

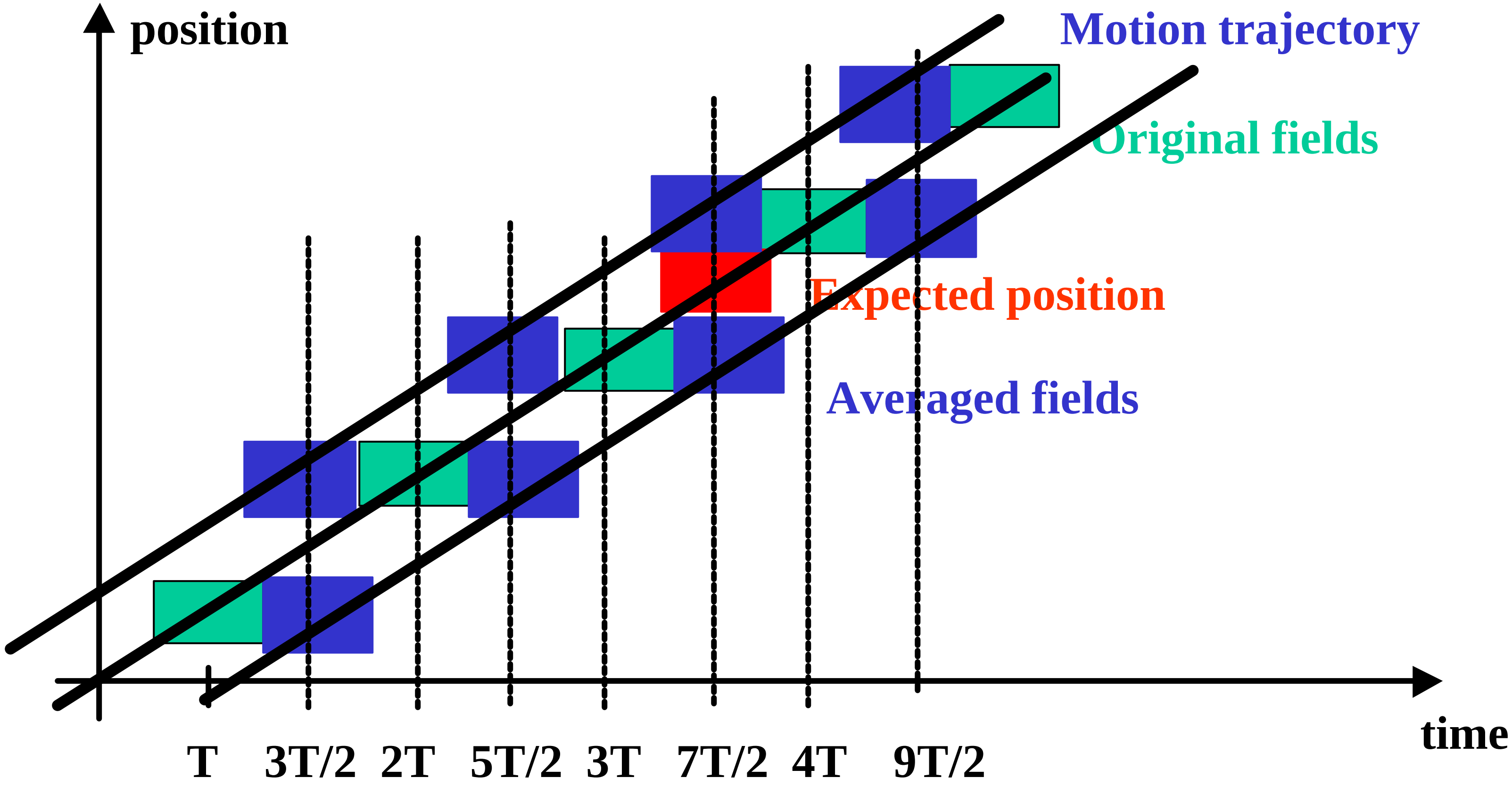


In a DSP fashion: $I_{out}(n) = 1/2\,[\,I_{fc}(n) + I_{fc}(n-1)\,]$ at $t=n(T/2)$. By Z transf. $|\,H(z)\,| = |\cos(p\, f_t\, T)\,|$ with f_t temporal freq on the screen.

Field repetition (3)

- **For the object tracking viewer, Field repetition gives rise to visible artifacts: low speeds introduce a blur, high speeds generate double images.**
- **The output sequence is OOEE rather than OEOE required for correct interlacing output fields.**
  - **The problem is tackled by adapting the display deflection.**
- **Field repetition cannot solve the line-flickering, since every line is scanned two times (and so the line period is 64 us instead of 32us of 100 Hz SD-TV).**

Field averaging (1)



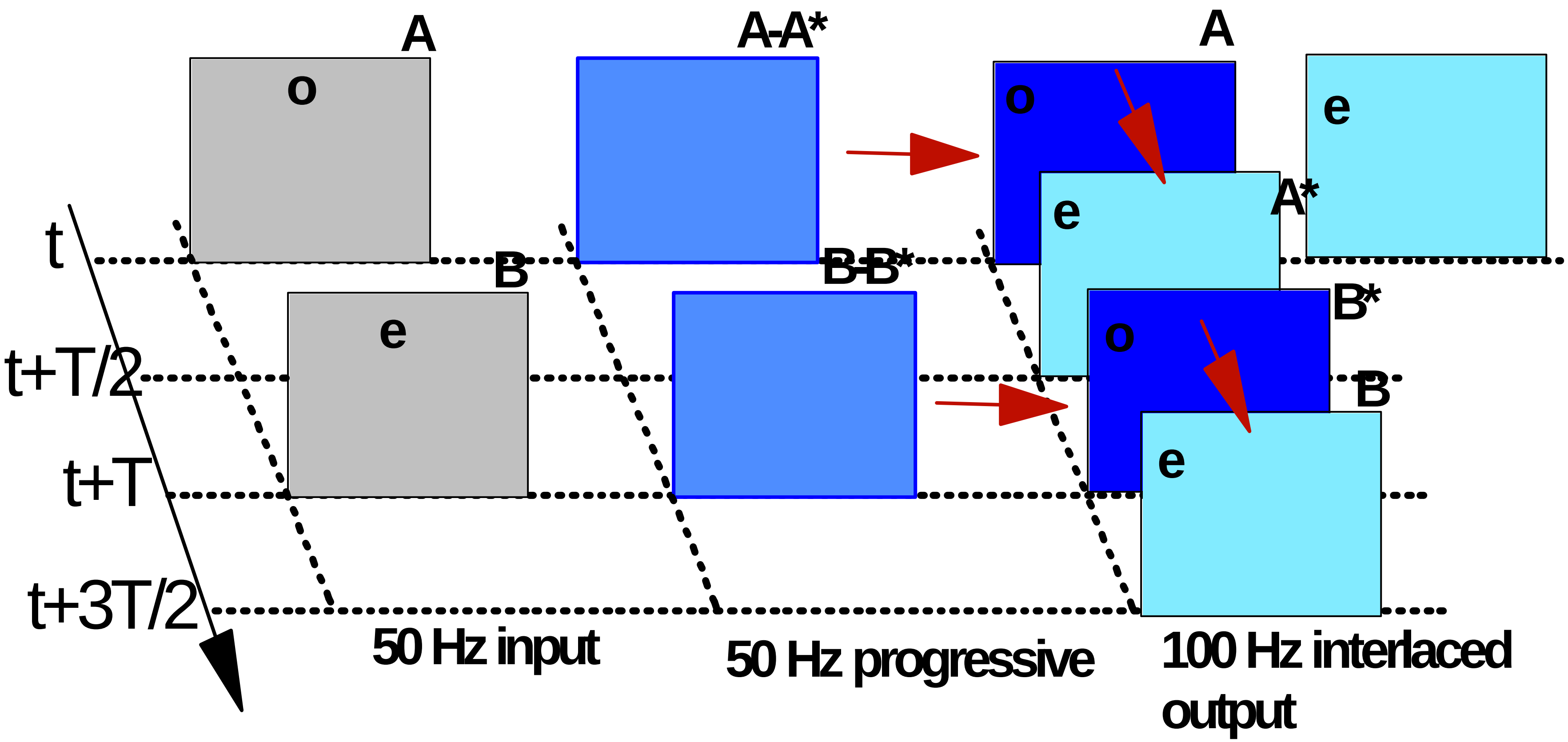
Odd fields: $I_{out}(\underline{x}, t) = I_{fc}(\underline{x}, t)$ **if** $t\%T=0$.

Even fields: $I_{out}(\underline{x}, t) = 1/2\,[I_{fc}(\underline{x}, t-T/2)+I_{fc}(\underline{x}, t+T/2)]$ **if** $t\%T=T/2$.

Field averaging (2)

- **If the viewer tracks the motion, he perceives more blur than what is obtained with Field repetition.**
- **This method can have advantages for the legibility of moving text:**
  - **No single echoes occur in case of motion, but two echoes symmetrically about the lettering and with a 50% lower intensity.**
- **Field averaging can satisfactory be used in critical stationary image parts.**

Philips "Digital Scan" 100 Hz (1)



Philips "Digital Scan" 100 Hz (2)

Ifc(x + (0,-1) , t-T/2)

Ifc(x, t+T/2)

Ifc(x + (0,+1) , t-T/2)

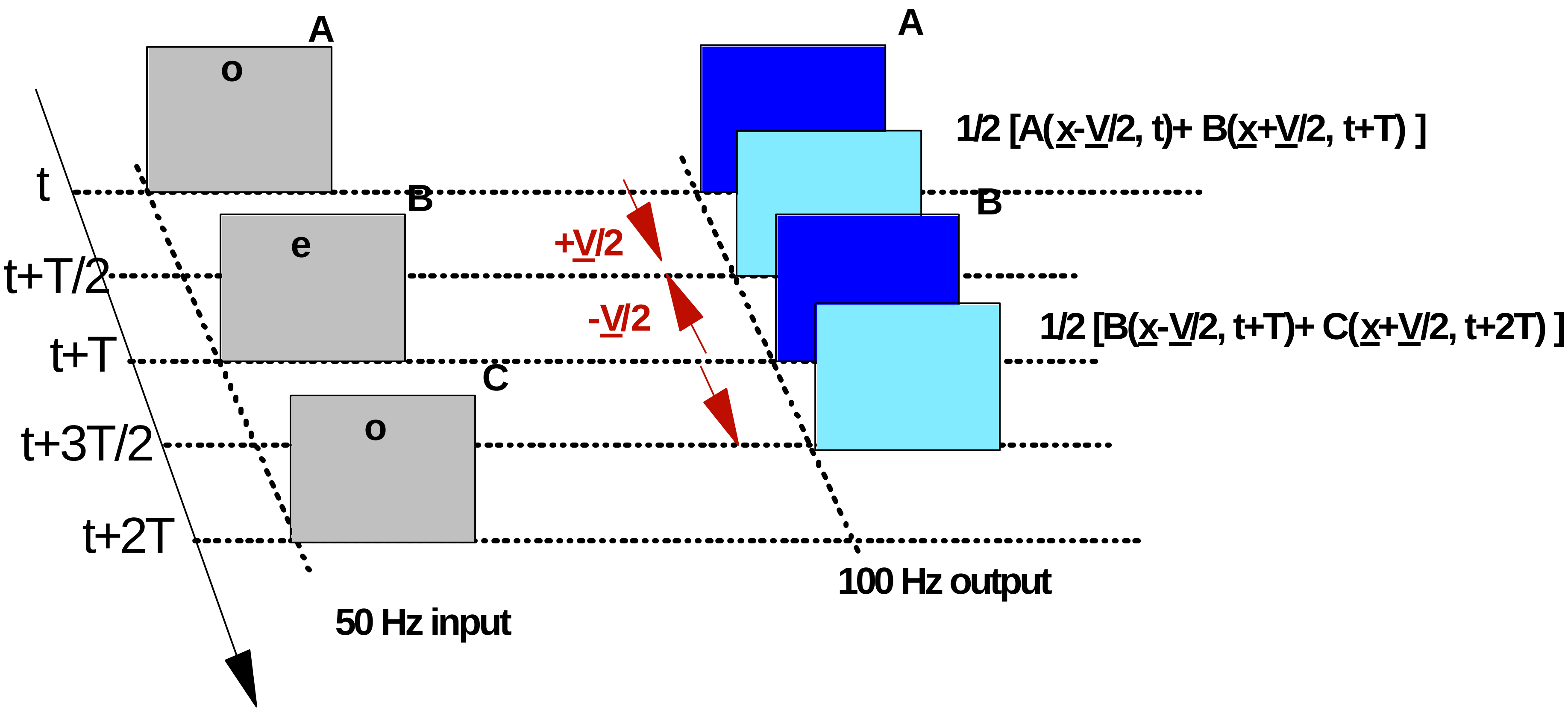
- **Field 1 (t%(2T) =0) :**
  - Iout (x, t) = Ifc (x, t).
- **Field 2 (t%(T/2)=0):**
  - Iout (x, t) = median[Ifc(x, t+T/2) , Ifc(x + (0,-1) , t-T/2) , Ifc(x + (0,+1) , t-T/2)].
- **Field 3 (t%T=0):**
  - Iout (x, t) = median[Ifc(x, t-T) , Ifc(x + (0,-1) , t) , Ifc(x + (0,+1) , t)].
- **Field 4 (t%(3T/2)=0):**
  - Iout (x, t) = Ifc(x, t-T/2).

Ifc(x + (0,-1) , t)

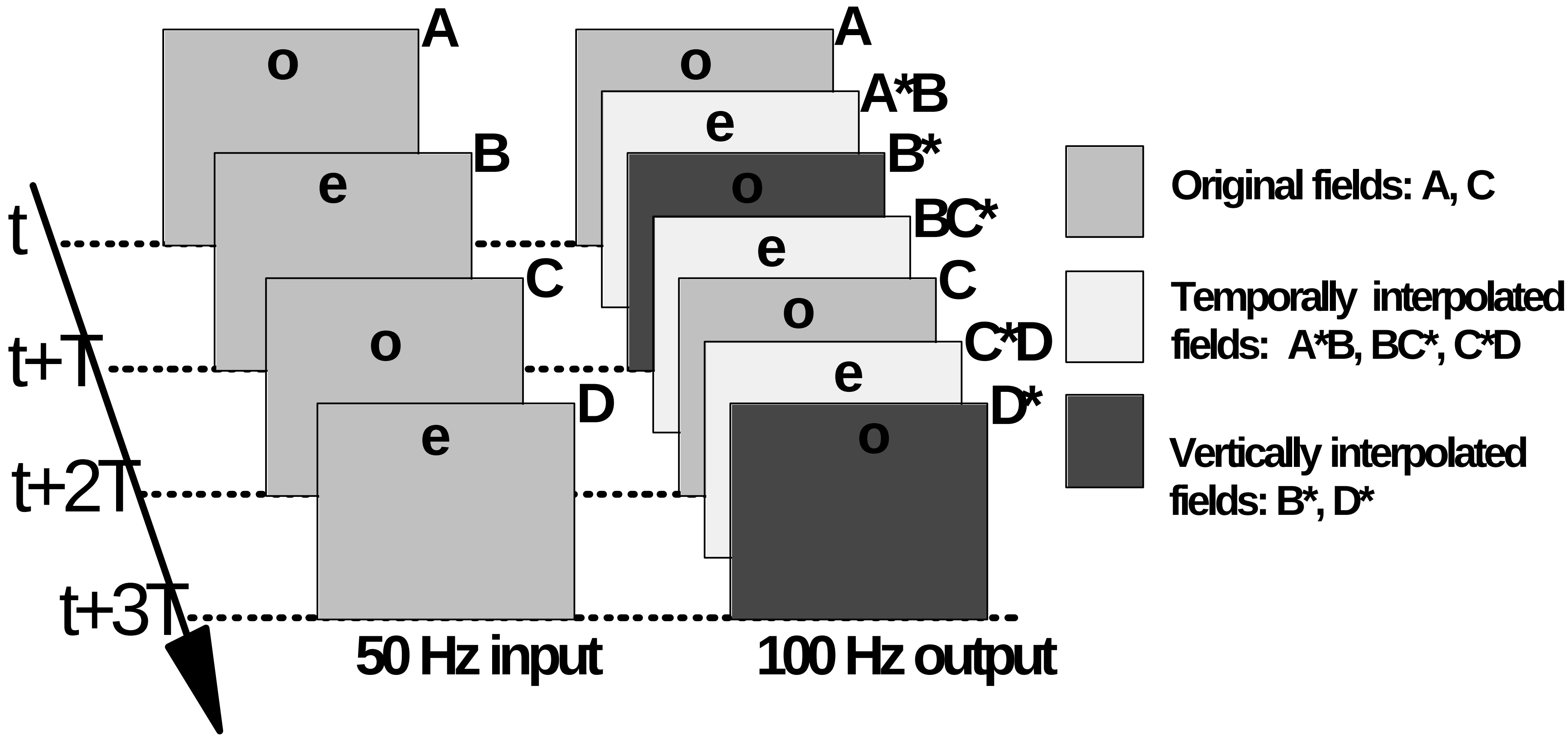
Ifc(x , t-T)

Ifc(x + (0,+1) , t)

Motion Compensated field averaging



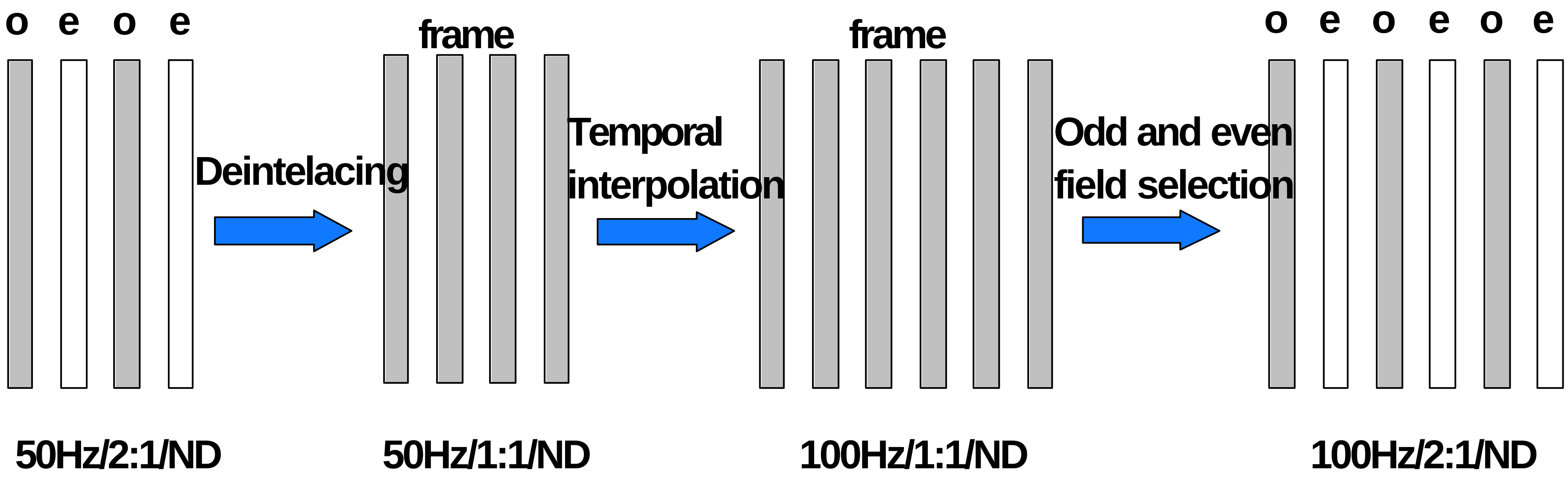
Philips “Natural Motion” 100 Hz



Philips "Natural Motion" 100 Hz

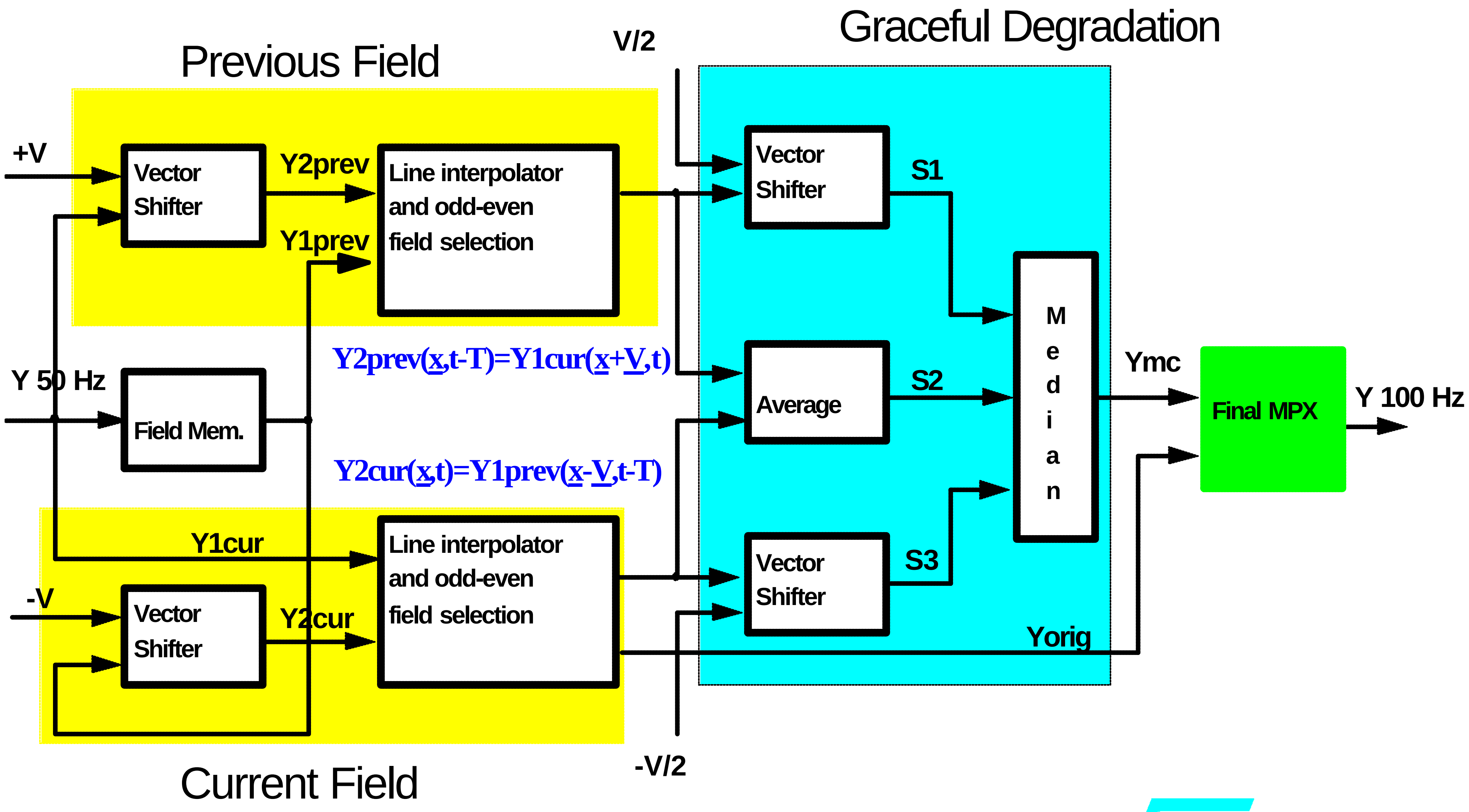
- **Only every fourth field in the output sequence is an original, all the others are interpolated to guarantee the parity changes.**
- **The fields marked with *, such as B*, contain the reconstructed missing lines instead of the original lines: being B an even field, B* is an odd field.**
- **The intermediate fields are marked with two letters, as A*B, to indicate that they are temporally interpolated using fields with the same parity.**

50 to 100 Hz multistage approach



The de-interlacing process is applied contemporary to both fields, in order to get available all the lines of the two fields during the temporal interpolation computation.

Interpolation block diagram



Vertical/Temporal Median Filtering (1)

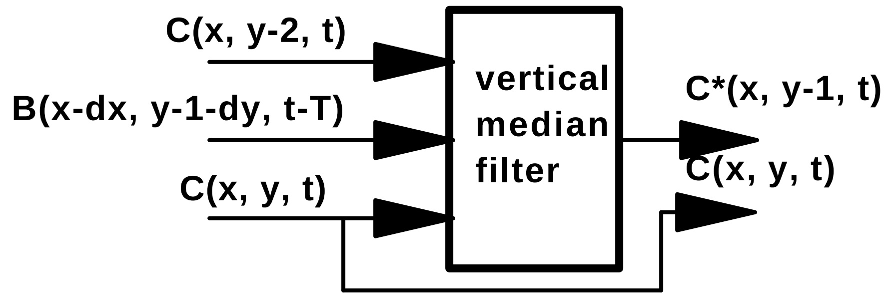
- **Referring to the couple of fields B and C, a vector $\underline{V}_{CB}=(d_x , d_y)$ is assigned to block (i, k) of $C(\underline{x}, t)$, if there is the best match with block $(i+d_x, k+d_y)$ of $B(\underline{x}, t-T)$.**
- **De-interlacing process:**
  - **the missing lines C* of the current field $C(\underline{x}, t)$ are at first obtained with the motion compensation, that is, $C^*(\underline{x}, t)=B(\underline{x} - \underline{V}_{CB}, t-T)$.**
  - **The missing lines B* of the previous delayed field should be computed as $B^*(\underline{x}, t-T)=A(\underline{x} - \underline{V}_{BA}, t-2T)$, if vectors $\underline{V}_{BA}$ were properly stored in a field memory.**

Vertical/Temporal Median Filtering (2)

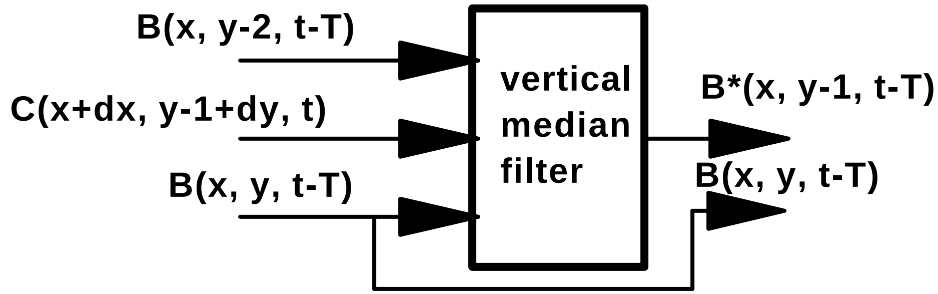
- However, field A is not available at the same time: it could be by using more than one field memory.
- This solution would require two field memories for the luminance to store A and B, when C is the current field.

- **Approximation to de-interlace field B in order to minimize the number of field memories:**
  - $B^*(\underline{x}, t-T) = C(\underline{x} + \underline{V}_{CB}, t)$
- **The approximation is legitimate because of the high coherence of MV computed by a recursive search (true) Motion Estimation approach.**

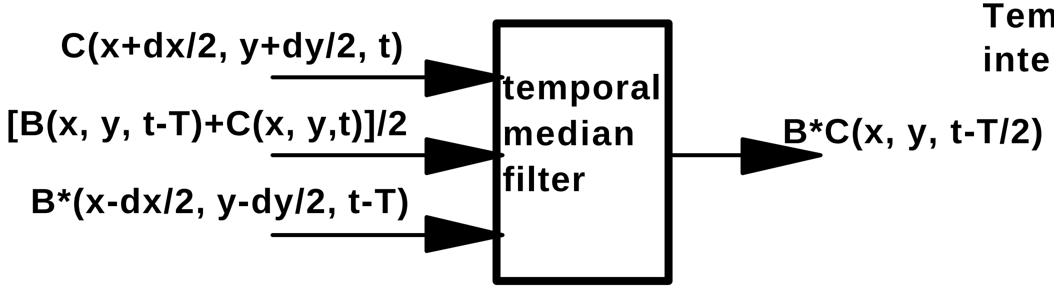
Vertical/Temporal Median Filtering (3)



Progressive current frame demultiplexed in original C lines
and reconstructed C* lines.



Progressive previous frame demultiplexed in original B lines
and reconstructed B* lines.



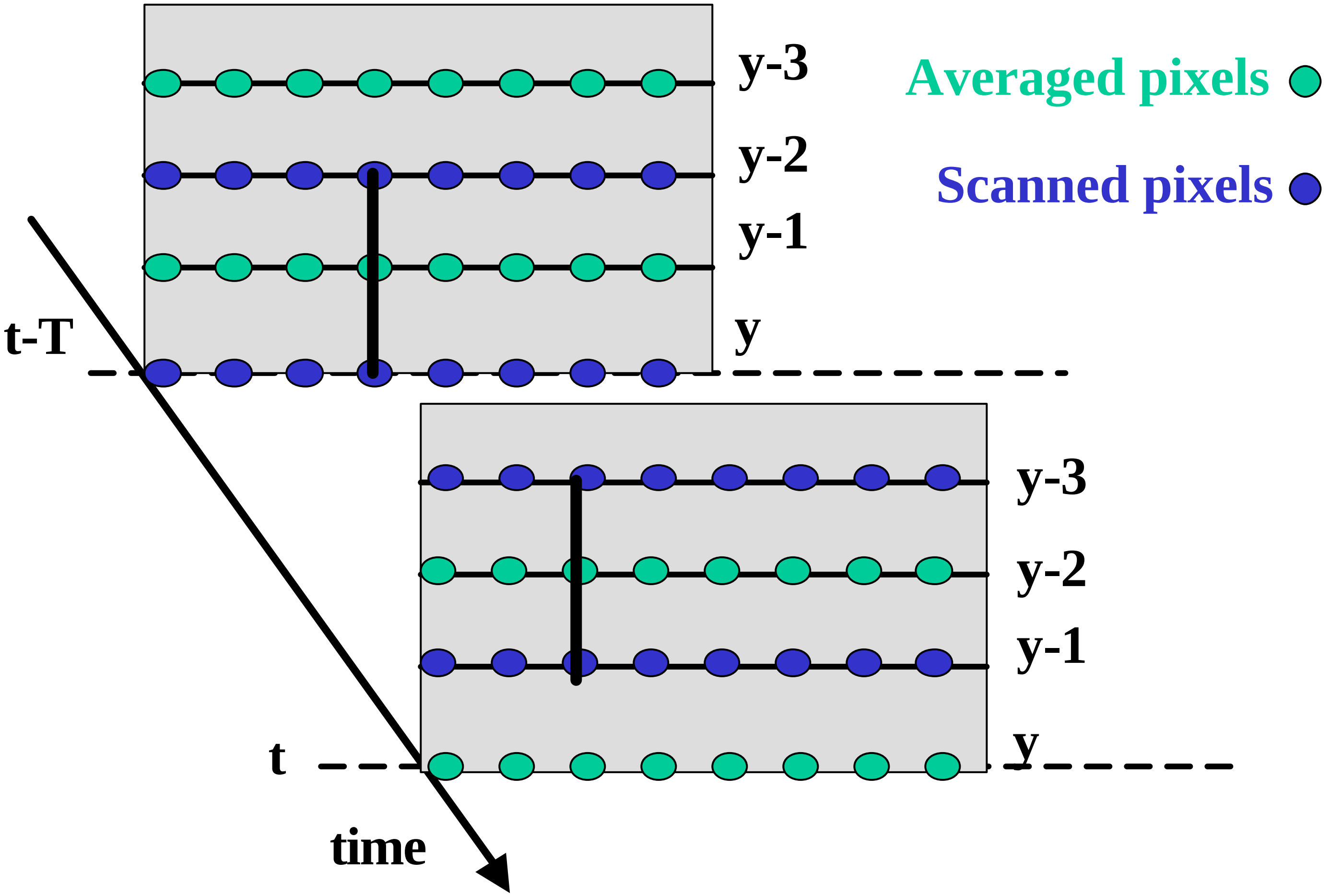
Temporal interpolation of the intermediate B*C field

$\underline{V}_{CB}=(d_x , d_y)$

De-interlacing or Line Rate Doubling

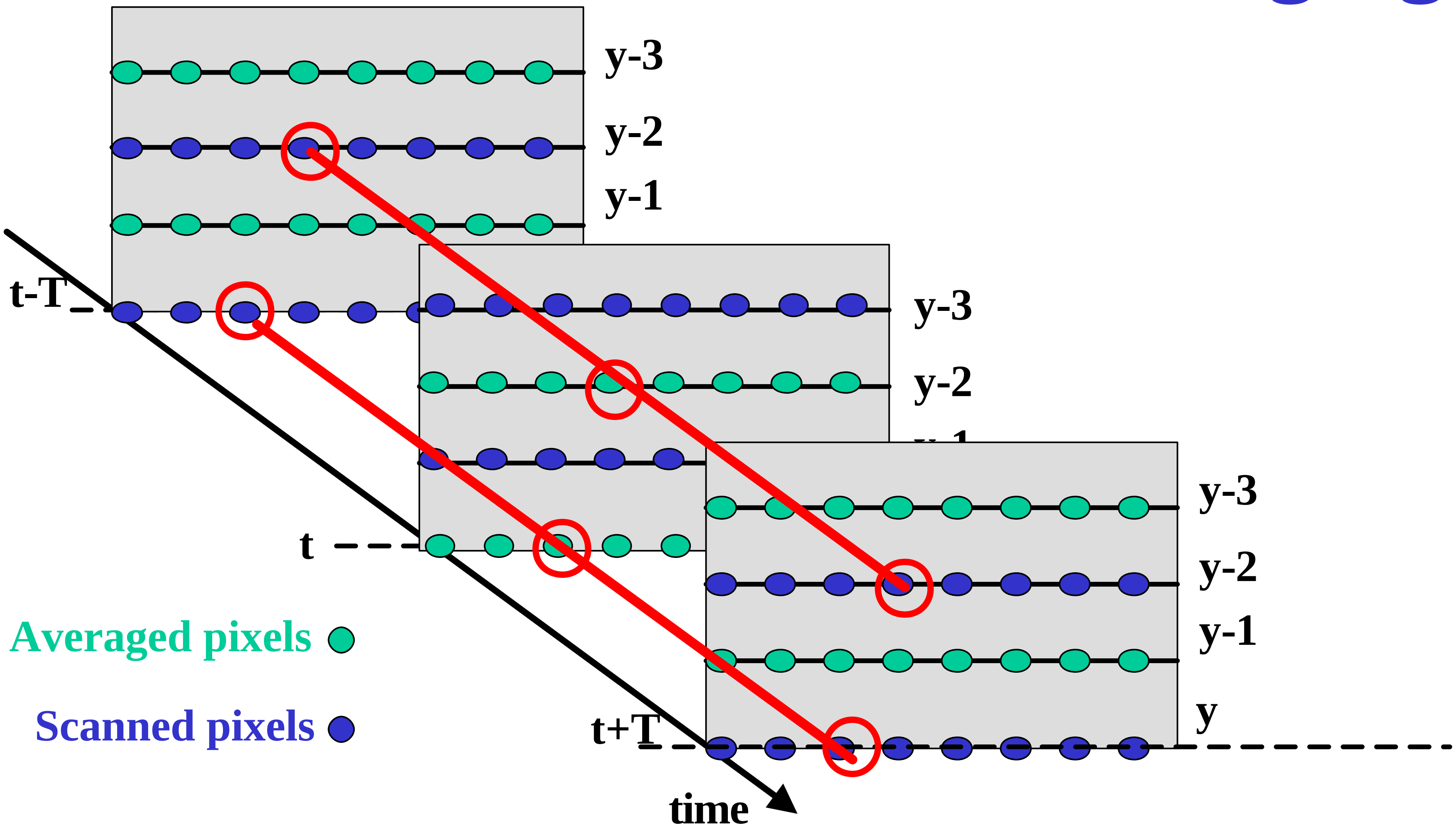
- **The interlace technique is as a form of bandwidth reduction that was introduced in the early days of TV not to save channel capacity, but merely to lower the operating frequencies in the equipment.**
- **FRD on interlaced video signals requires the indispensable operation of Line Rate Doubling.**
- **We assume to have pictures with lines that are already time compressed (I_{LC}), through a line memory device (FIFO), with T_L period of a time-compressed line.**

LRD: intra averaging



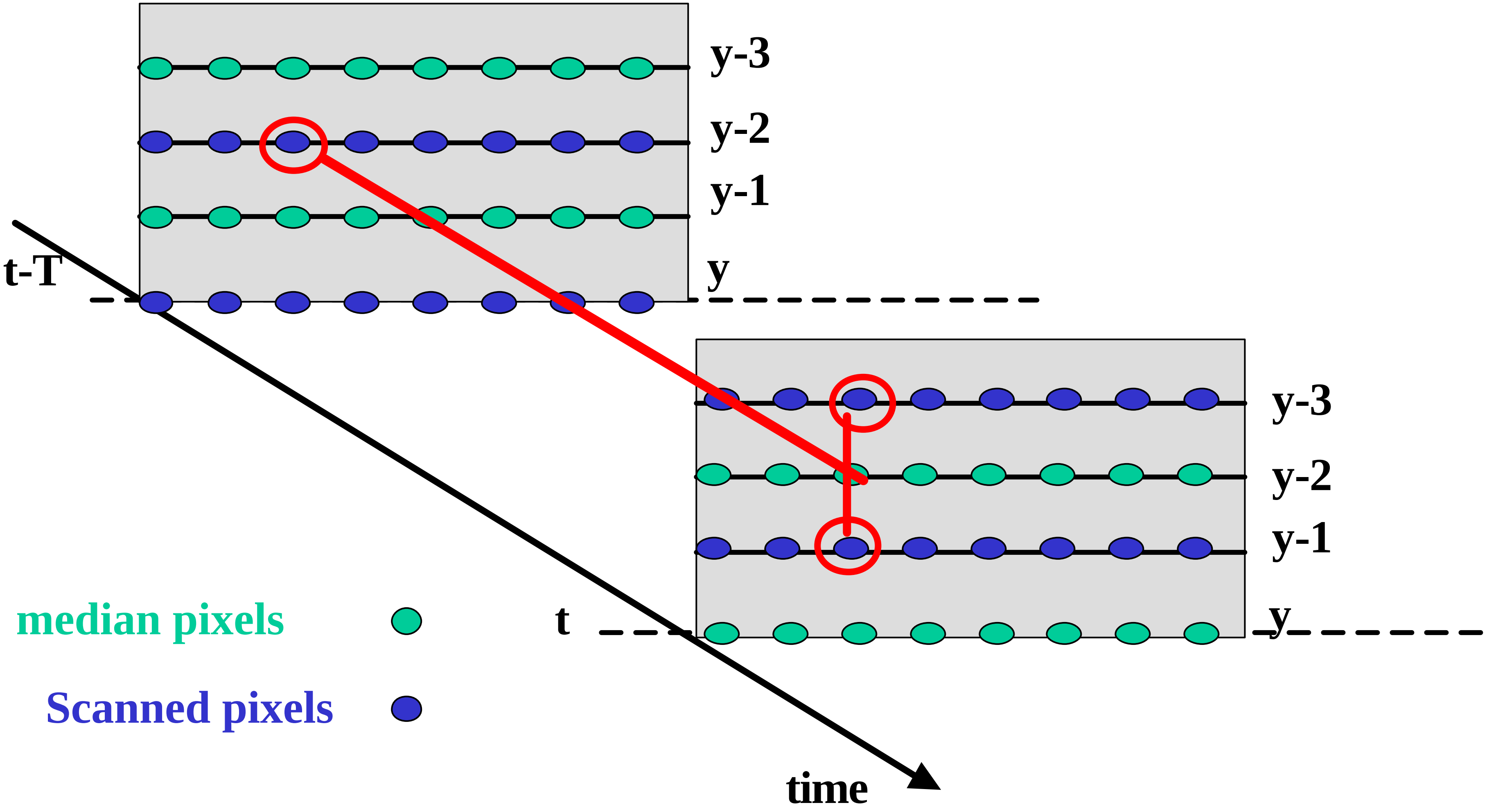
$$I_{out}(\underline{x}, t) = 1/2\ [\ I_{LC}\ (\underline{x}, t\text{-}T_L/2) + I_{LC}\ (\underline{x}, t\text{+}T_L/2)]$$

LRD: inter averaging



$$I_{out}(\underline{x}, t) = 1/2 \, [\, I_{LC}(\underline{x}, t-T) + I_{LC}(\underline{x}, t+T)]$$

LRD: median filtering

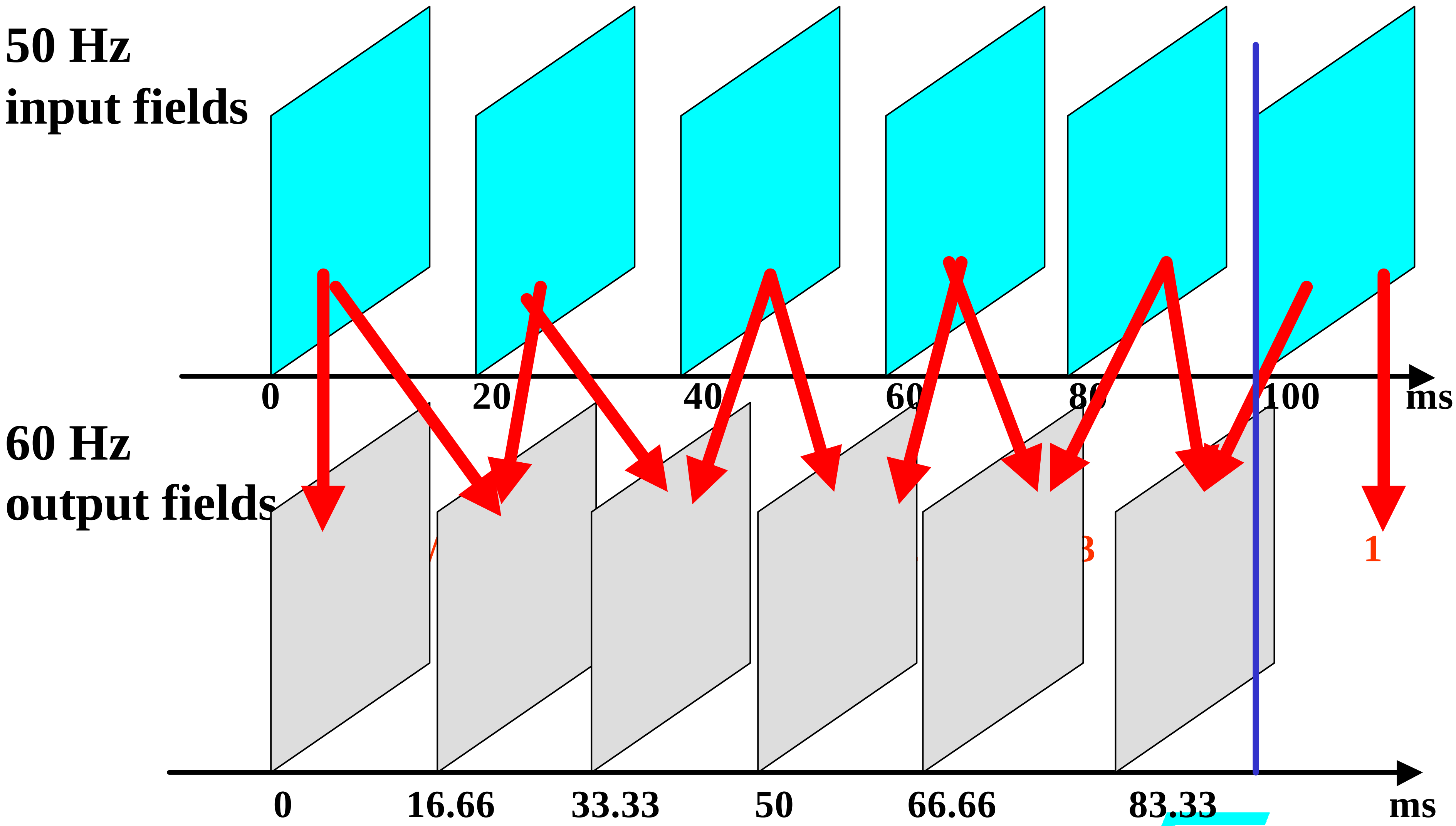


Iout(x,y-2, t)=median[ILC(x,y-1,t) , ILC(x,y-3,t), ILC(x,y-2,t-T)]

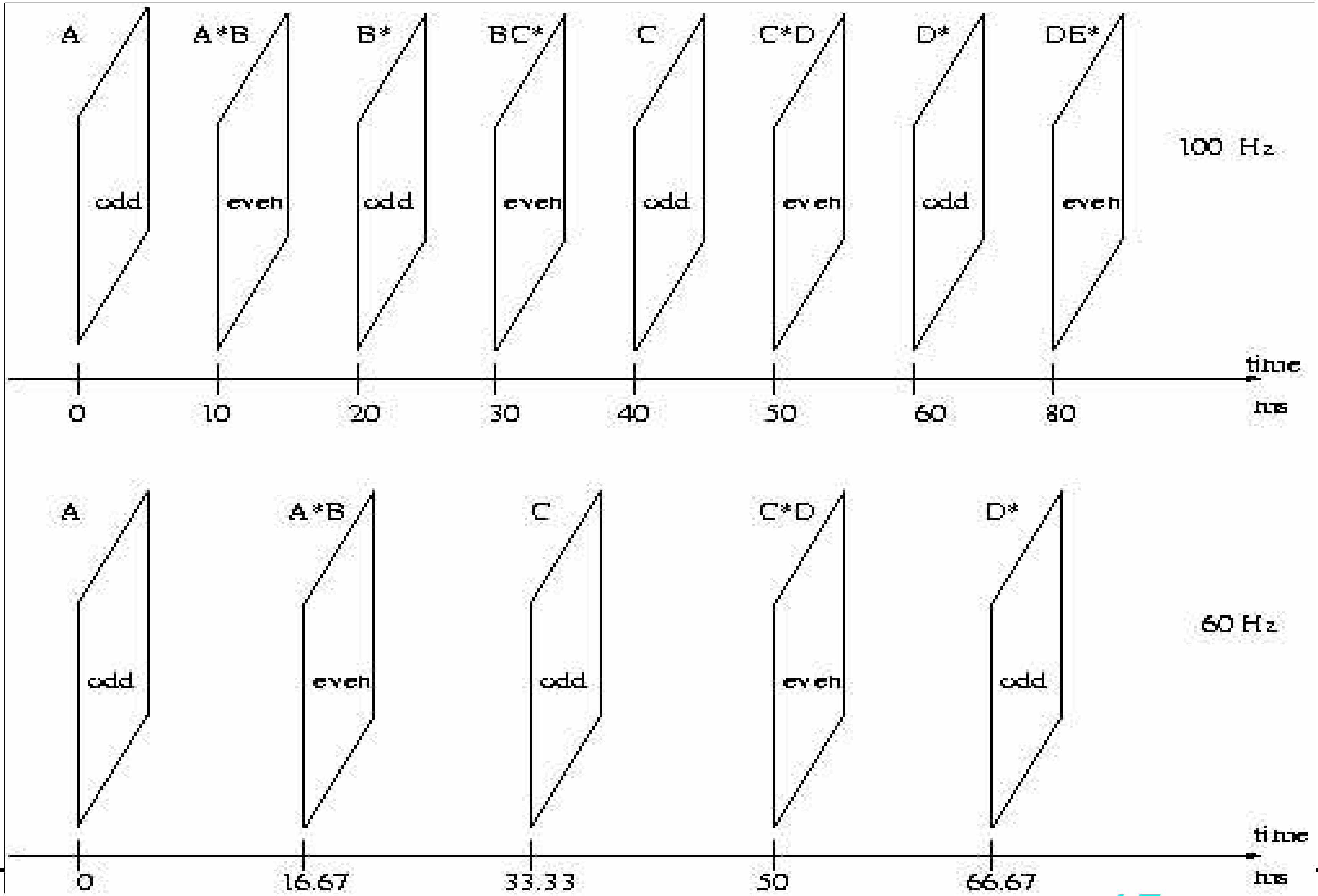
LRD: summary

- **Intra-averaging:**
  - blur of vertical detail; no motion defects;
  - no elimination of line flicker and vertical alias;
- **Inter-averaging:**
  - good quality on stationary images;
  - blur and serration in moving parts of the picture
- **Median-filtering:**
  - good line flicker reduction in stationary image parts;
  - non linar filtering (imperfect reproduction of sinusoids).
- **Motion Compensation** $I_{out}(\underline{x}, t) = I_{LC}(\underline{x}-\underline{d}, t-T)$**:**
  - vertical alias cannot be removed completely in moving parts, unless the MV equals an odd integer number of frame lines.

50 Hz to 60 Hz conversion



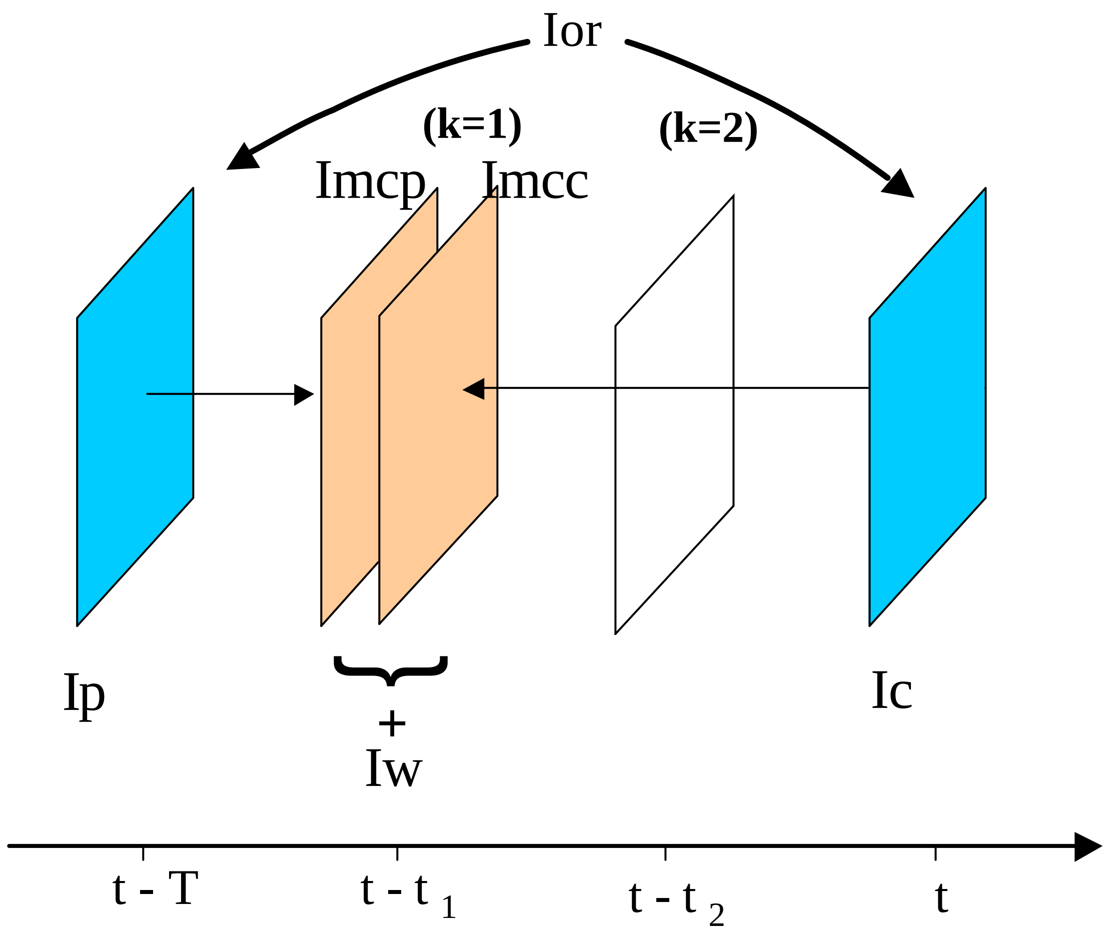
100 Hz to 60 Hz simple conversion



H.263 temporal post-processing

I_p = previous frame
I_c = current frame
I_{post} = output frame
mc = motion compensated

n	K	Imc
4	1	Imcp
4	2	Imcp
4	3	Imcc
3	1	Imcp
3	2	Imcc
2	1	Imcp



Example for n = 3 e k = 1

$$I_{post}(x,y,t-t_k)=median(I_{or}, I_{mc}, I_w)$$