Styrofoam: Protecting Symbol Fidelity in Screen▶Camera Communication

David Ramirez, Robert LiKamWa, and Jason Holloway
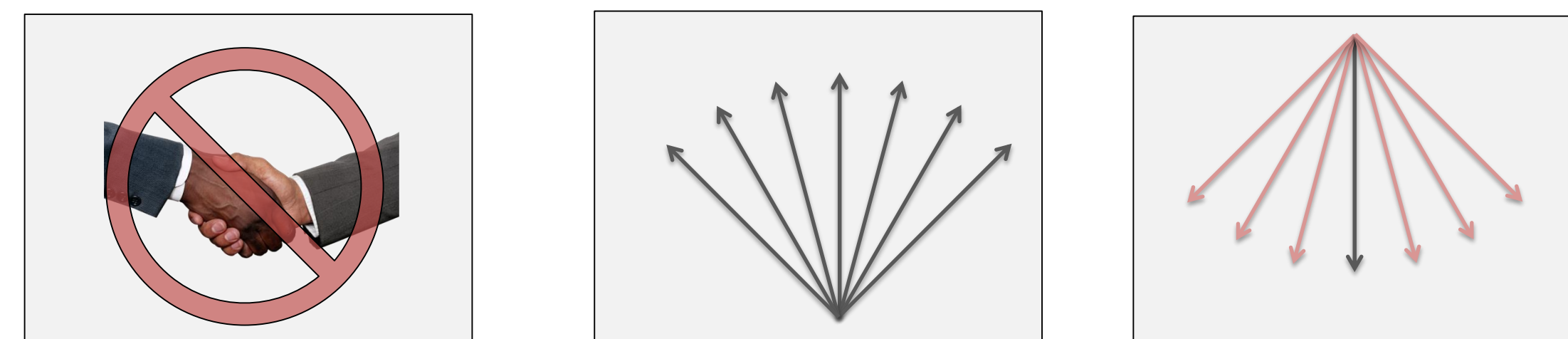Department of Electrical and Computer Engineering, Rice University

Screen-to-camera link

Sending data from a screen to a camera carries multiple benefits, including:

Pairless infrastructure

Multi-cast transmission
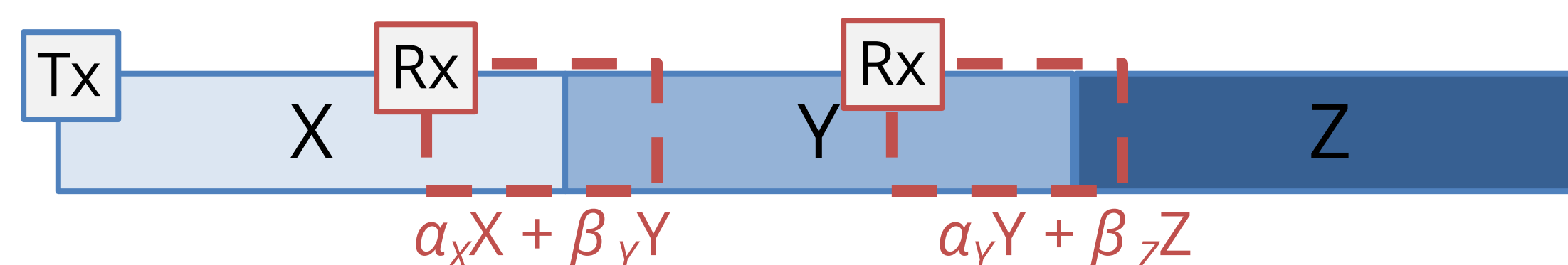
Targeted interaction

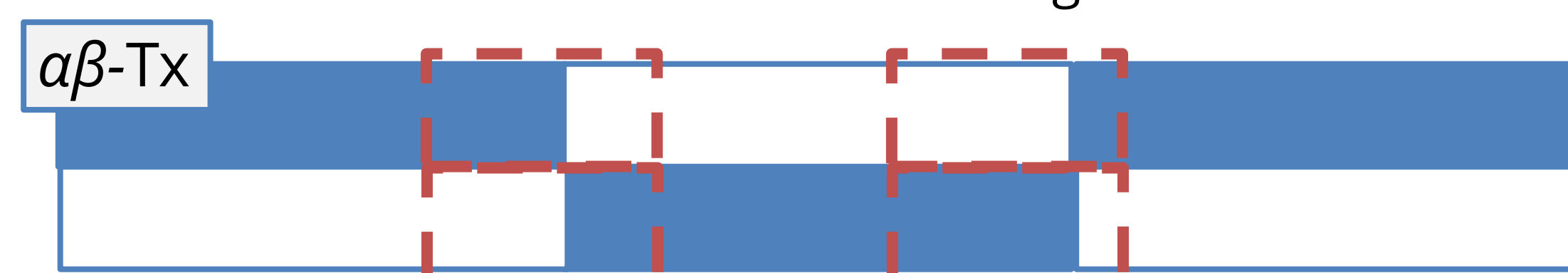A high datarate screen-to-camera link enables many scenarios, such as:

Sending personal audio at a museum

Enhanced-media menus & maps

Wearable Transmissions

Inter-symbol Interference

Symbol transmission in VLC Links are challenged by *Inter-symbol interference,* in which a single camera exposure receives multiple symbols.
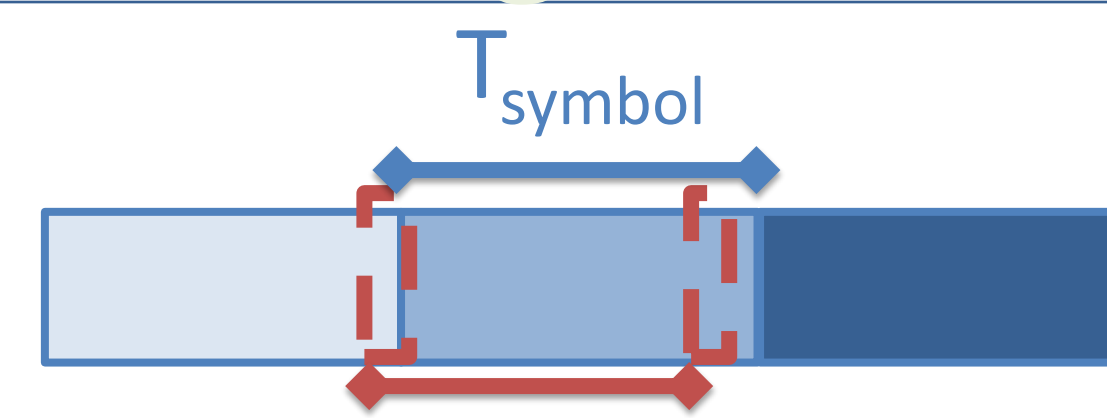
$$\alpha_X X + \beta_Y Y \qquad \alpha_Y Y + \beta_Z Z$$

We measure interference proportions through **alternating timing blocks** on the barcode grid.

$\alpha\beta$-Tx

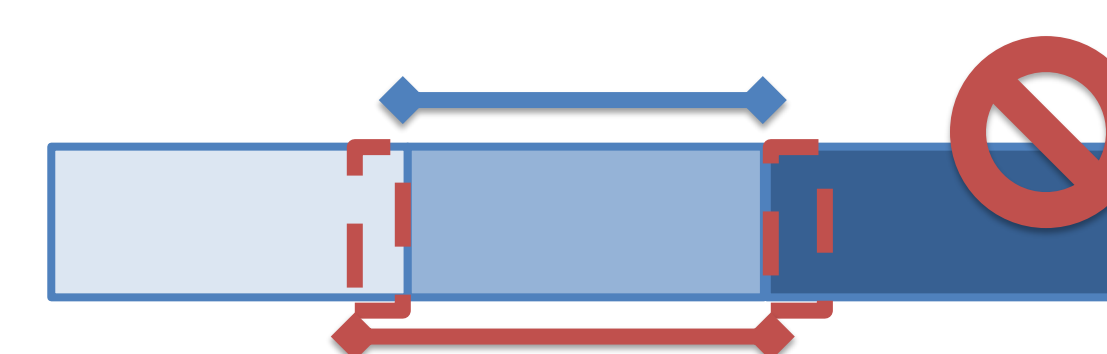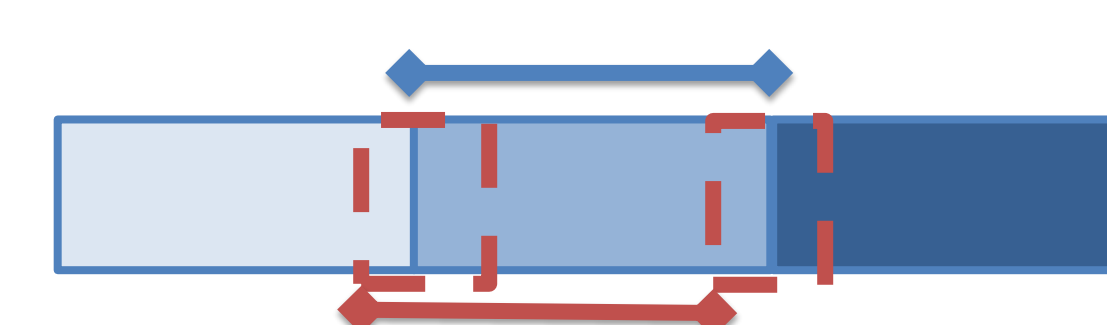## Frame Scheduling

Symbols are separated by a *Symbol Interval*.

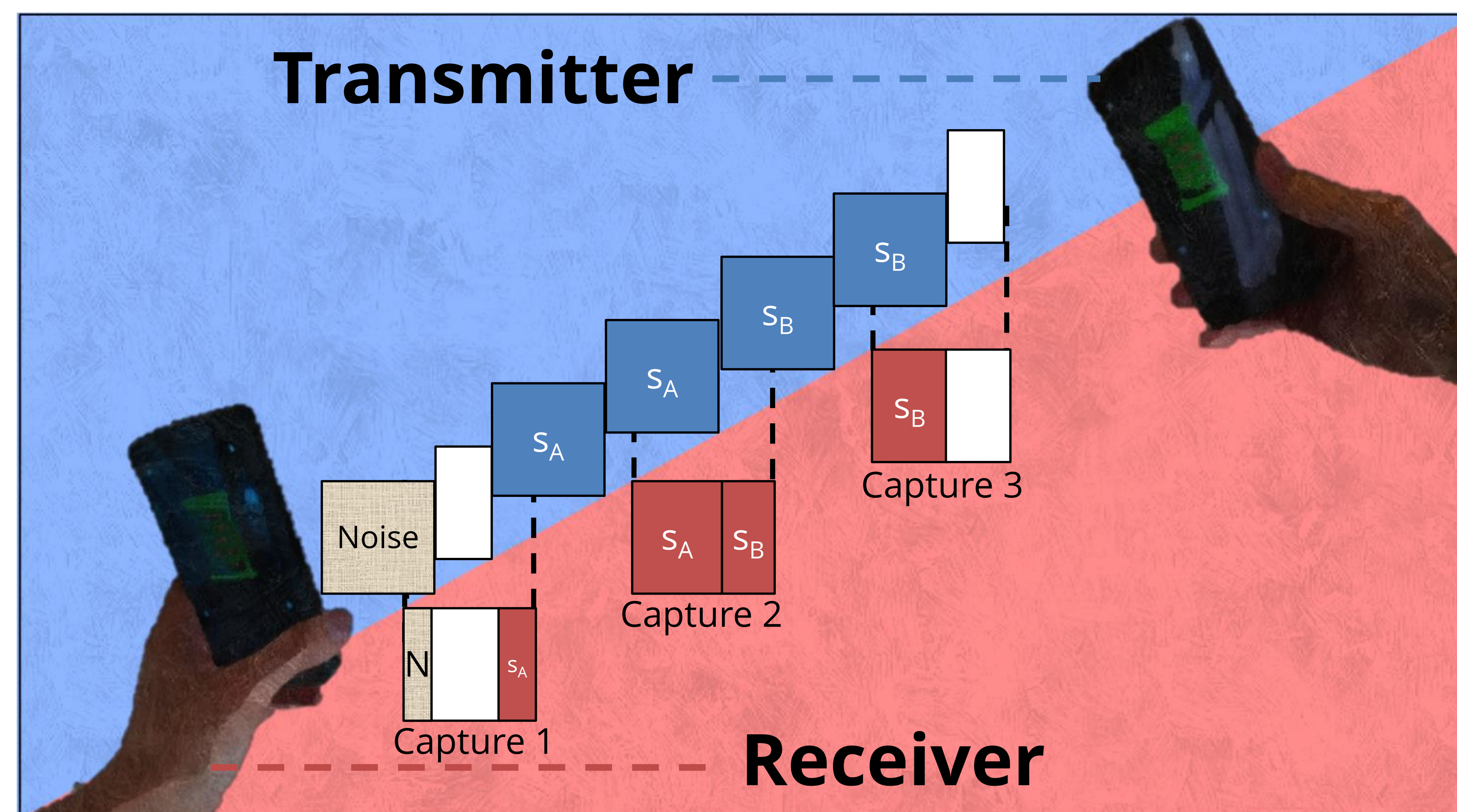Exposures are separated by a *Capture Interval*.

T_{symbol}

$T_{capture}$

Symbol interval must be *larger* than the capture interval to ensure that each symbol is exposed.

This also guarantees that if a symbol undergoes interference, it is captured at least twice.

Styrofoam characterizes and constrains inter-symbol interference

Transmitter

s_A s_B

Noise

N s_A
Capture 1

s_A s_B
Capture 2

s_B
Capture 3

Receiver

Resolvability with Styrofoam Blocks

A sequence of captures can be represented as a system of equations, where each capture introduces an **equation** with **one or two variables**:

$$r_j = \alpha_j s_A + \beta_j s_B \qquad r = \alpha_1 s_A$$

Mixed capture Pure capture

As any symbol in a mixed capture appears in two captures, this creates a chain of captures which can eventually be resolved by a pure capture.

We periodically insert *Styrofoam Blocks* – blank frames – to ensure pure captures occur regularly, limiting the latency of resolvability.
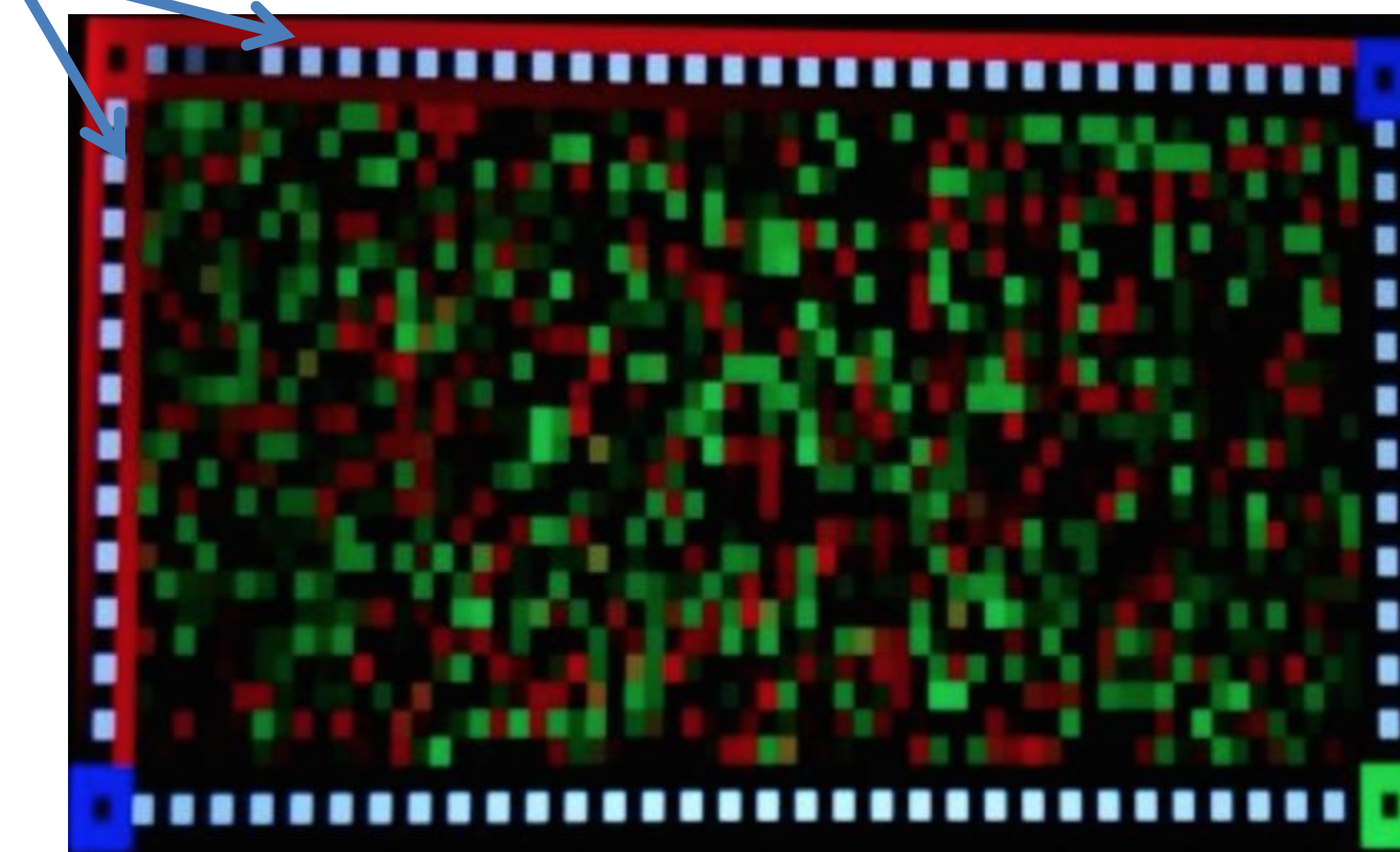
Our timing assures a sequence between Styrofoam blocks will have a symbol corresponding to α (or β) > half of a frame's exposure. The remainder of the exposure can be filled by the Styrofoam block. Thus, Styrofoam blocks only need be half as long as symbol transmissions.

We schedule the display sequence as having:
each Styrofoam block transmitted for one frame, and
Each symbol transmitted for two frames.

| | X | X | Y | Y | Z | Z | |

Styrofoam Barcode

$\alpha\beta$ timing blocks

A column set to a max value represents max exposure under screen/camera conditions.

Alternating timing columns are activated for every other exposure to encode α and β.

Symbols are transmitted on the remaining grid.

Contributions

The Styrofoam Project:
- Characterizes inter-symbol interference timing
- Constrains frame rates to ensure symbol visibility
- Interposes blank frames to ensure resolvability

In the future, we plan to study the effects on noise sources on the discretization of symbol levels. This will include investigations on
- Physical screen-camera geometry
- Camera filter "bleeding"
- Display color fidelity

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References
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