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Broadband Sensors Optical Wireless Local Area Networks

National Science Foundation Award

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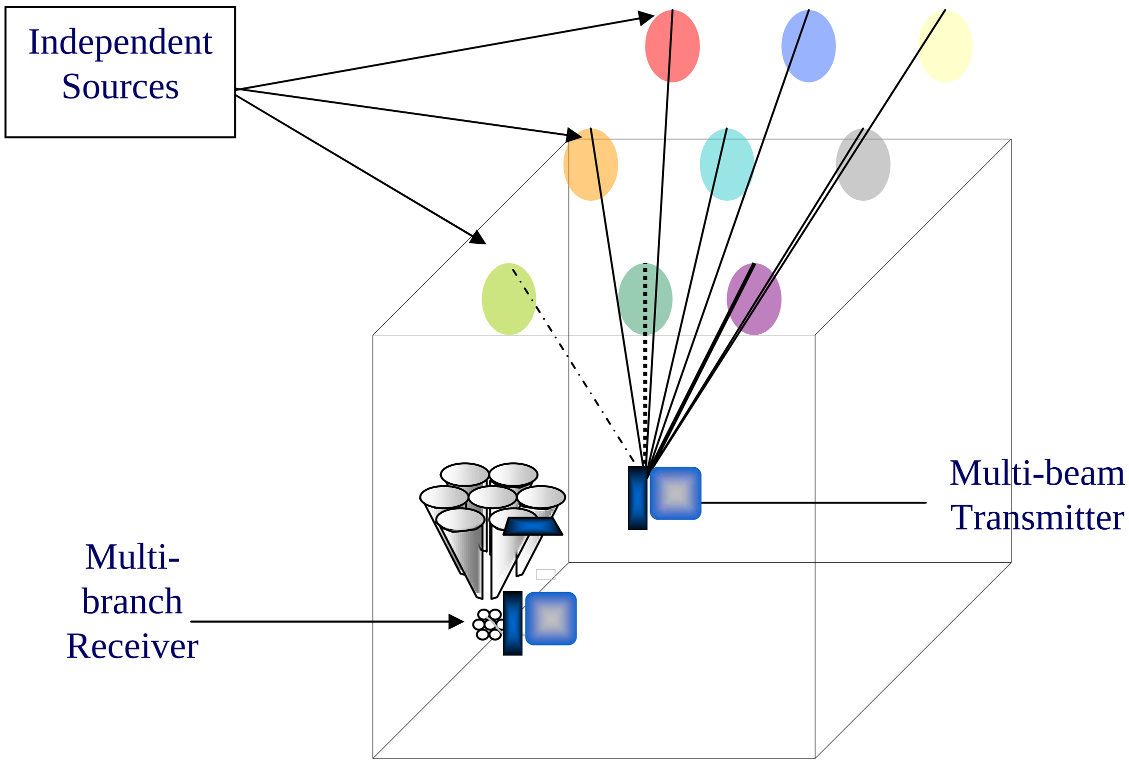
Project Abstract

The objective of this research is to design wireless optical communication techniques for integration into sensor networks. The approach is to employ low-cost, compact-sized, and power-efficient white LEDs and photolithographic optical transceivers, in conjunction with indoor environment channel modeling and spatially coded multiple access techniques, to realize secure broadband communications interfaces among sensors.

The intellectual merit of this work lies in its potential to provide capacity and quality-of- service superior to conventional radio frequency techniques. This research directly addresses the challenges in obtaining parallel independent optical communications channels that will provide a means of spatial diversity, which, in turn, will result in improved power budget. Furthermore, use of photolithographic (thin film) beam splitters and combiners and white LEDs for transceiver optics pose a challenging, but promising, new area for sensor networks communications.

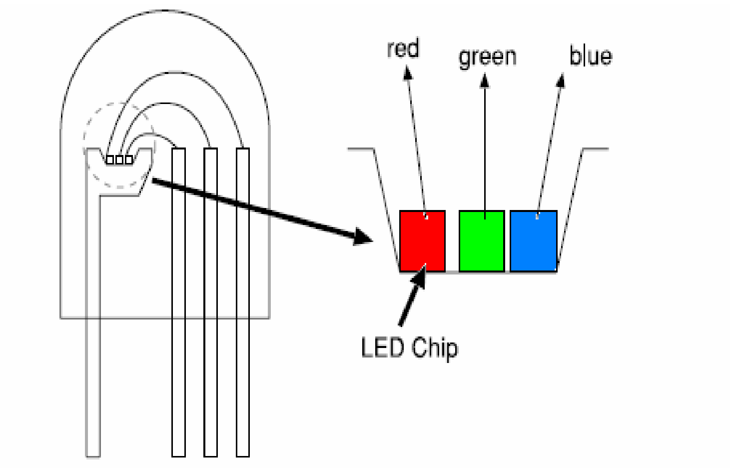
The broader impacts of this research include more efficient and more reliable communication links for facilities that rely upon sensors for collecting/distributing vital information (hospitals, planes, ships, factory plants). Co-existence with RF sensitive devices will make the proposed system robust and attractive for universal usage. Furthermore, this research will contribute to education by being incorporated into lectures on optics and wireless communications science and engineering, providing opportunities for undergraduate and graduate students to obtain multi-disciplinary hands-on experience on issues related to wireless optical communications system design and networking.

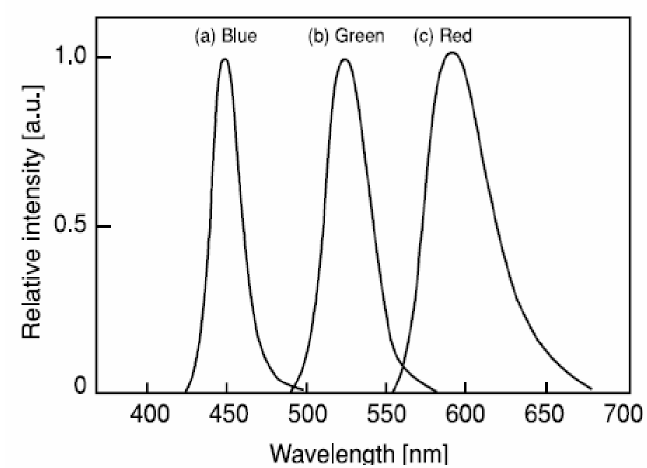
Multi Spot Diffusing Configuration



Multi-Chip W-LED

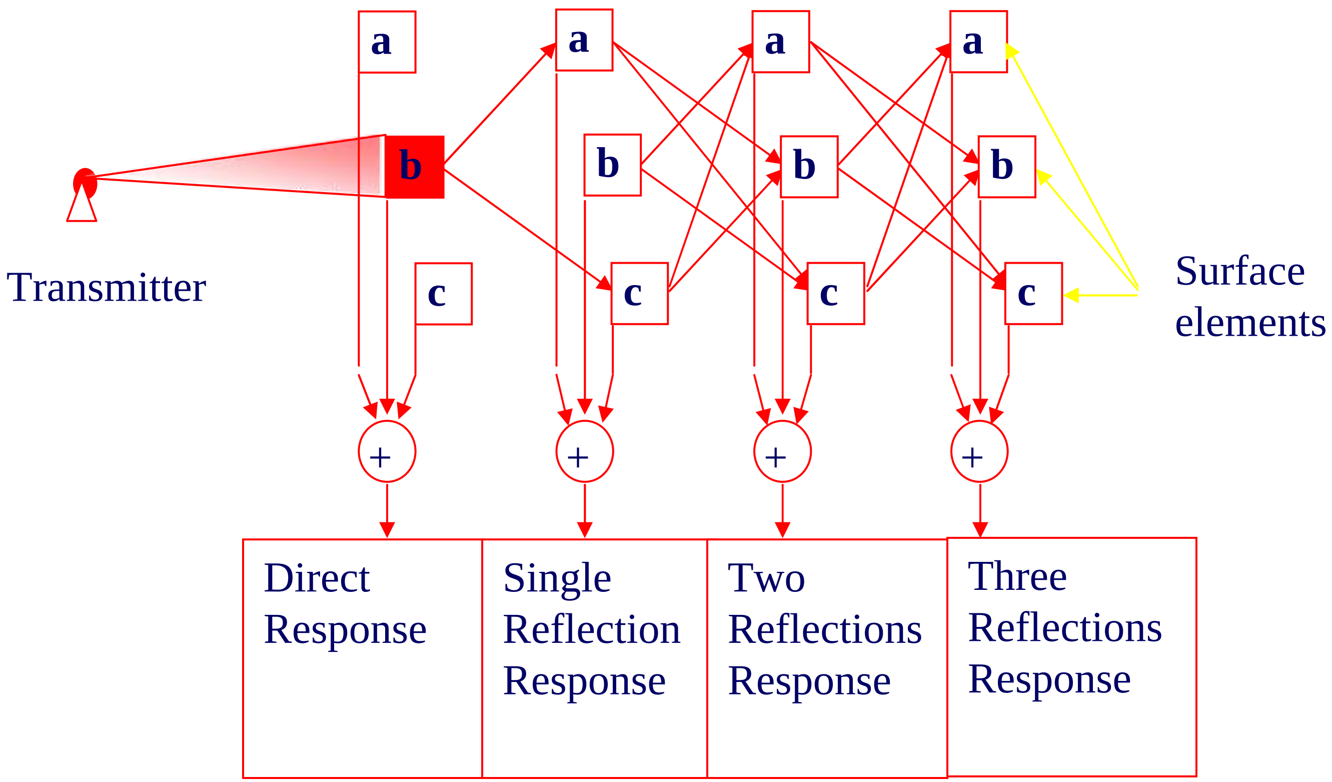
- Multi-chip: mixes the light from LEDs of three primary colors.
  - changing the mixture ratio of three primary colors ➔ different colors.
  - It is hard to simultaneously modulate three LEDs.
  - Using LEDs of different colors for different cells and exploit this multi-chip property for multiplexing.



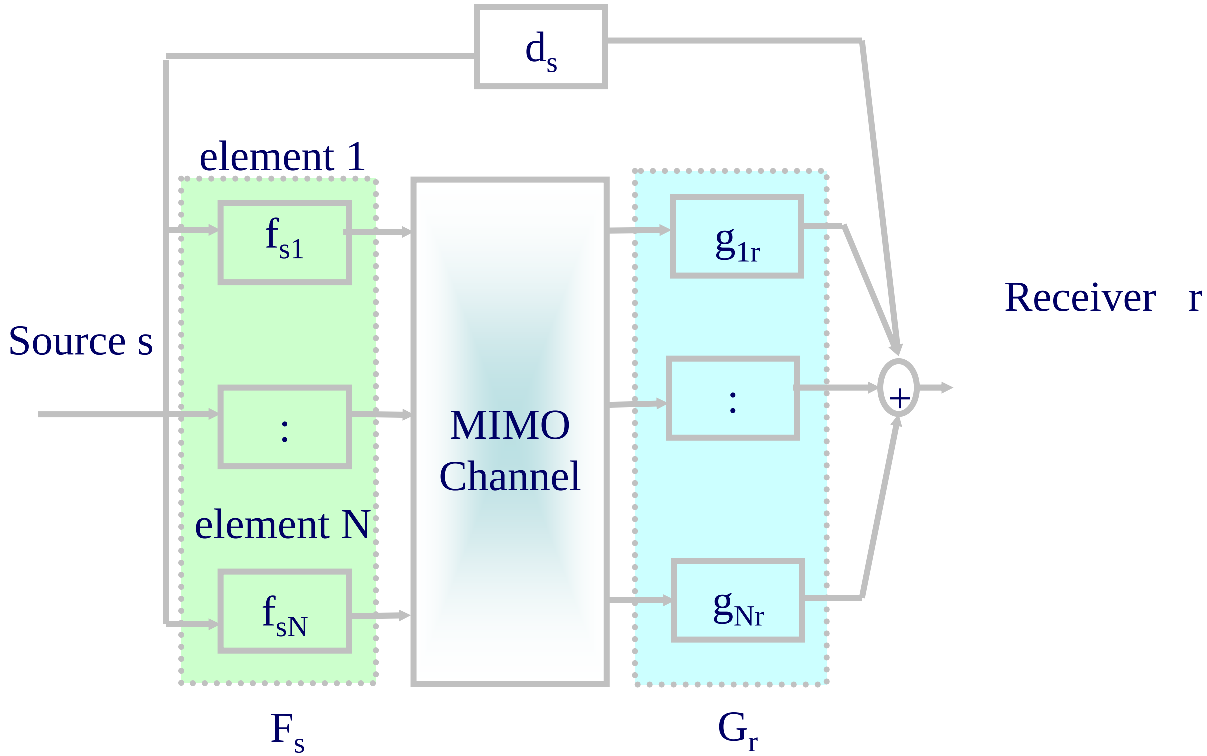


Multi-chip-type white LEDs.
(InGaN blue + AlInGaP green + AlGaAs red)

Channel Impulse Response



Channel Impulse Response



Channel Impulse Response

- The impulse response can be expressed as

$$H = D \cdot G_r + F_s \cdot \Phi_n \cdot G_r$$

- where

$$D = [d_1 \quad \cdots \quad d_N]$$

$$F_s = [f_{s1} \quad \cdots \quad f_{sN}]$$

$$\Phi_n = \begin{cases} I_{NxN} + \phi + \phi^2 + \phi^3 + \cdots \phi^{n-1} & ,n \geq 2 \\ I_{NXN} & ,n = 1 \end{cases}$$

$$G_r = \begin{bmatrix} g_{1r} \\ \vdots \\ g_{Nr} \end{bmatrix}$$

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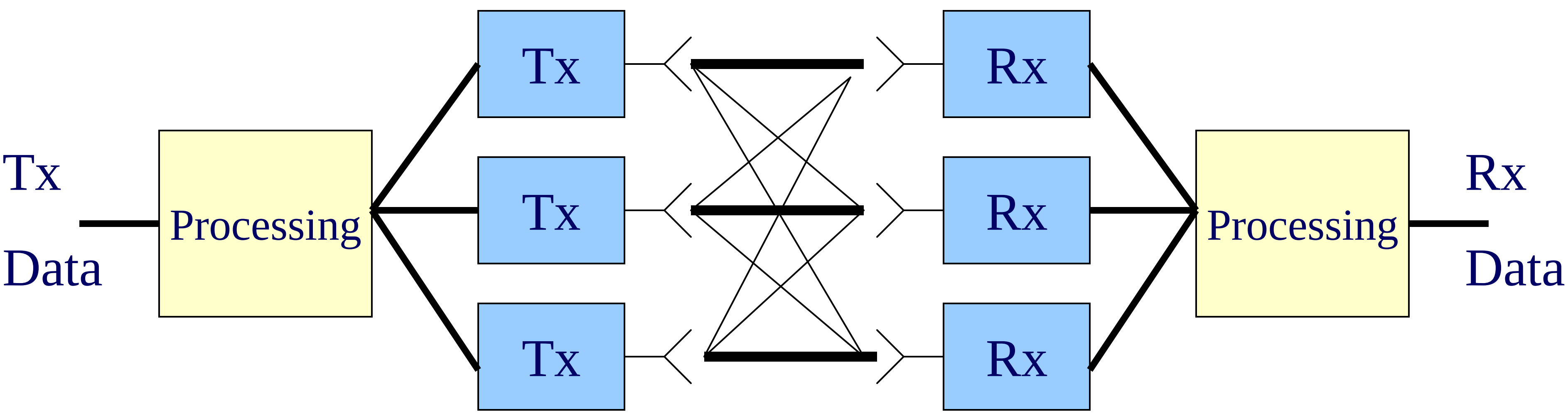
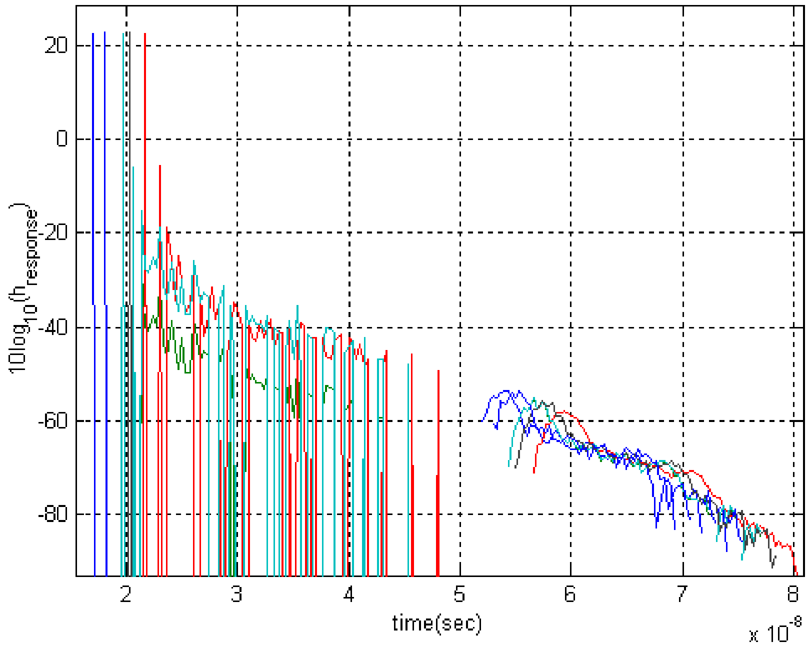
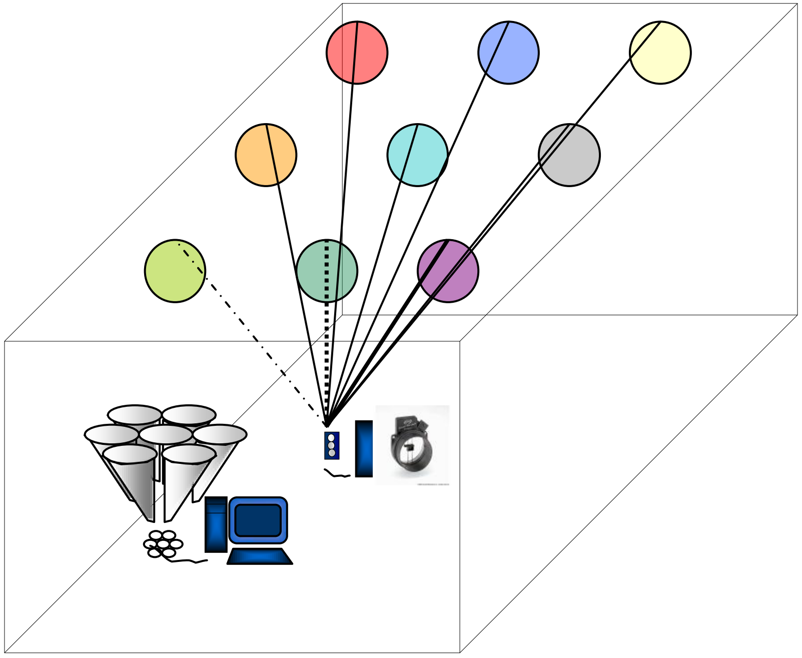
Spatial Coding



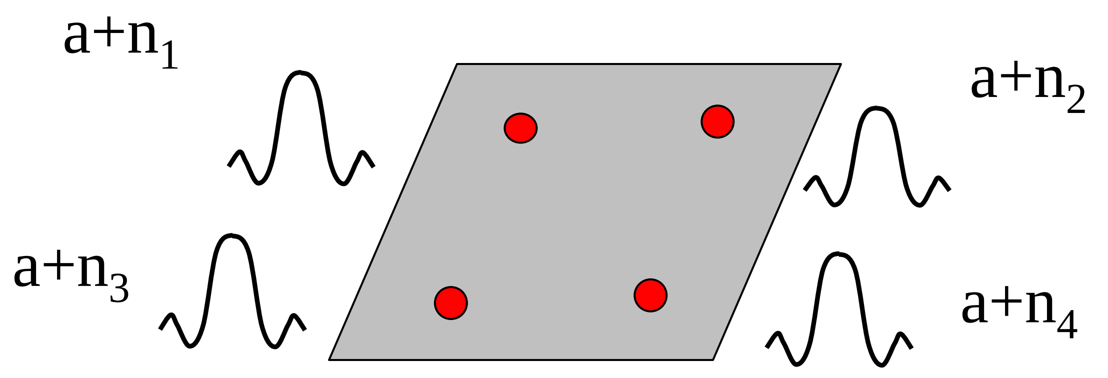
MIMO Channel

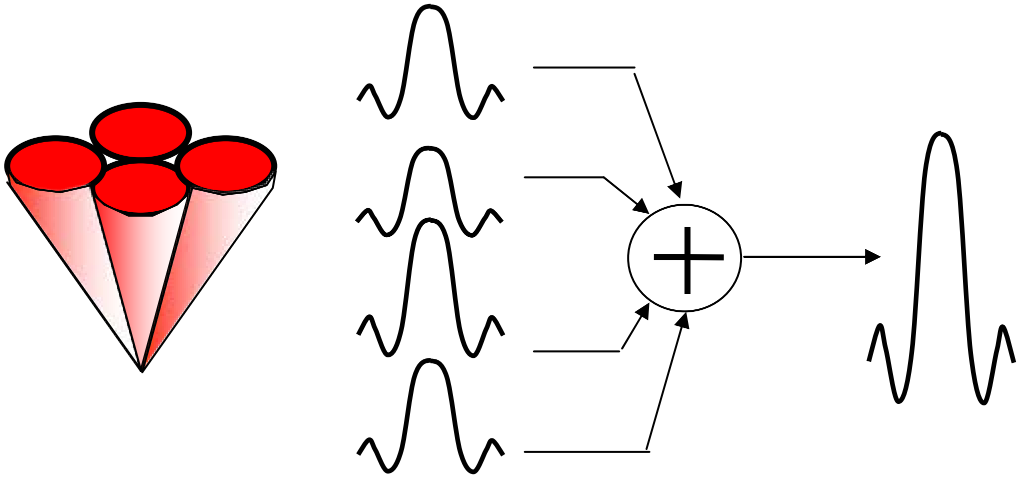




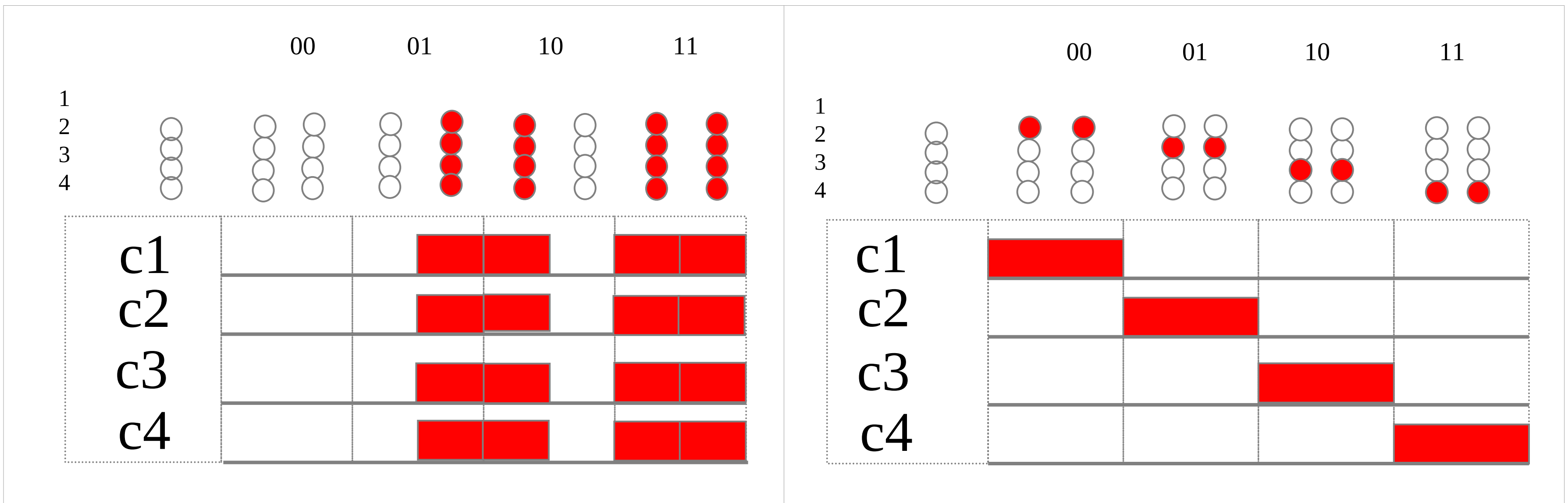
The channel impulse responses as seen by a 7-branch receiver.

Space Diversity with Combining





Orthogonal Spatial Coding



(a) (b)