MIMO-Diversity Switching Techniques for Digital Transmission in Visible Light Communication

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Contents

- Objectives of the Research
- MIMO-Diversity Switching Techniques
  - Hardware
  - Software
- Focusing Gap between Concentrator and Photodiode
- Conclusion
Comparison between MIMO and Diversity Signaling in White LED Transmission

<table>
<thead>
<tr>
<th>Multiple In, Multiple Out (MIMO)</th>
<th>Diversity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increases data rate; improves spectral efficiency.</td>
<td>Increases signal-to-noise ratio; improves shadowing.</td>
</tr>
<tr>
<td>Every LED is important because each LED emits a different part of the data stream.</td>
<td>A damaged LED does not affect a transmission.</td>
</tr>
<tr>
<td>Does not generate intersymbol interference (ISI).</td>
<td>Generates ISI.</td>
</tr>
</tbody>
</table>
Solutions

- A MIMO-diversity switching scheme:
  - MIMO scheme by default;
  - Diversity scheme is activated when the line-of-sight between the LED and the photodiode is blocked.
- Can be done using either hardware or software technology
MIMO Transmitter Types
MIMO Transmitter

MIMO-Diversity Switchable Transceiver - Transmitter
MIMO Receiver

MIMO-Diversity Switchable Transceiver - Receiver

ICL7660S

CA3140

BPV10 or SFH213

VCC

10uF

R1 = 2kΩ
R2 = 200kΩ
R3 = 100kΩ
R4 = 100kΩ
C5 = 30pF

VCC

10uF

R3

R4

VCC

10uF

R2

10kΩ

BPV10 or SFH213

ICL7660S

CA3140

LM6172(1a)

LM6172(1b)

µC

LM6172(2a)

LM6172(2b)

To IN1 To IN2

BPV10 or SFH213

10kΩ

VCC

10uF

10uF

10uF

VCC

10uF
Software Method: COM port Switching

MATLAB generates signals which exit through COM ports.
Circuits

\[ H = \begin{bmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \end{bmatrix} \]
Experiments

- 4 x1W white LEDs were used
- 5 cm apart
- Original baud rate is set at 115200 bps.
- MIMO data rate = 230400 bps.
- One LED was blocked using a finger.
  - Circuit was switched to diversity;
  - Diversity data rate = 115200 bps.
- One LED was misaligned.
  - Circuit was switched to diversity;
  - Diversity data rate = 115200 bps.
Experimental Results

- The switching speed of COM ports is much slower than hardware switching.
- For both the shadowing and alignment tests, COM port switching takes about 0.34s to switch from MIMO to diversity.
- Hardware switching is immediate.
Comparing Various Techniques

<table>
<thead>
<tr>
<th>Number of Char.</th>
<th>MIMO</th>
<th>Diversity</th>
<th>Port Switching</th>
<th>Circuit Switching</th>
</tr>
</thead>
<tbody>
<tr>
<td>40</td>
<td>0.0399s</td>
<td>0.0799s</td>
<td>0.3999s</td>
<td>0.0601s</td>
</tr>
<tr>
<td>80</td>
<td>0.0809s</td>
<td>0.1609s</td>
<td>0.4609s</td>
<td>0.1211s</td>
</tr>
<tr>
<td>120</td>
<td>0.1238s</td>
<td>0.2429s</td>
<td>0.5234s</td>
<td>0.1835s</td>
</tr>
<tr>
<td>160</td>
<td>0.1629s</td>
<td>0.3238s</td>
<td>0.5834s</td>
<td>0.2435s</td>
</tr>
</tbody>
</table>
Focusing Issues with Concentrator
Focusing Gap

\[ P_{\text{gap}} = f \times s_r \times V_F \]

- \( f \) = focal length
- \( s_r \) = absolute spectral sensitivity
- \( V_F \) = maximum recommended forward voltage

\[ \frac{1}{f} = (n - 1) \left[ \frac{1}{R_1} - \frac{1}{R_2} + \frac{(n - 1)d}{nR_1R_2} \right] \]

where \( f \) is the focal length of the lens; \( R_1 \) is the radius of curvature of the lens surface closest to the light source; \( R_2 \) is the radius of the curvature of the lens surface farthest from the light source; \( d \) is the thickness of the lens; \( n \) is the refractive index of the lens material.
### Focusing Gap of Concentrators (Calculated* and Measured†)

<table>
<thead>
<tr>
<th>Magnification Factor</th>
<th>Focal Length (cm)</th>
<th>$P_{gap}^*$ (cm)</th>
<th>$P_{gap}^†$ (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>× 4.5</td>
<td>2.3</td>
<td>1.6445</td>
<td>1.7</td>
</tr>
<tr>
<td>× 6</td>
<td>3.2</td>
<td>2.2880</td>
<td>2.4</td>
</tr>
<tr>
<td>× 10</td>
<td>2.6</td>
<td>1.8590</td>
<td>2.0</td>
</tr>
<tr>
<td>× 15</td>
<td>1.2</td>
<td>0.8580</td>
<td>0.95</td>
</tr>
</tbody>
</table>
Conclusion

- We have provided a prototype design of a simple MIMO transmitter and receiver.
- Two techniques are suggested to switch between MIMO and diversity interchangeably: hardware (in-circuit) switching and software (COM port) switching.
- This switching enables efficient use of each technique’s advantages.
- An equation to calculate the focusing gap (between the photodiode and the concentrator) has been derived.
- This equation will become useful when we want to determine the real focal length of VLC consumer products in the future.