A Compact Tri-Polarization Antenna for MIMO Communication Systems

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   (Creation of Multipath-rich Environment)
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MIMO Technologies

Radiowave propagation

Tx array
Encoding with time and space domain

Rx array
Decoding with time and space domain

Multi-path propagation

Information theory and coding theory

Adaptive array and adaptive signal processing

Applications are from W-LAN to next-generation mobile wireless systems.
MIMO Propagation Channel Model

Path profile (indoor)

Equivalent circuit model based on SVD
Average Channel Capacity in iid Rayleigh Fading Environment

\[
\langle C_1 \rangle = m \int_0^\infty \log_2 \left( 1 + \frac{\gamma_0}{N_t} \lambda \right) p_{\text{unord}}(\lambda) d\lambda \\
\approx m \log_2 \left( 1 + \frac{\gamma_0}{N_t} \langle \lambda \rangle \right) \\
= m \log_2 \left( 1 + \frac{\gamma_0 N_r}{m} \right) \\
\approx N_r C_0
\]

Channel capacity is approximately proportional to the number of antennas when

\[
\{ C_0 \equiv \log_2 (1 + \gamma_0); \quad \gamma_0 \gg 1; \quad N_t = N_r \} \]
Increase of Channel Capacity

Use of Dual-Polarization Branches
Use of Triple-Polarization Branches

Compact MIMO Antenna
Dual-Polarization antenna

Triple-Polarization antenna

The tri-polarization antenna acts as a three-element MIMO antenna in the case of multipath-rich environment.

Compare

3 × 3 single-pol. MIMO

3 × 3 tri-pol. MIMO
Antenna Element

\[ \frac{\lambda}{4} \]

\( Z \)

\( H \)

\( V \)

4 cm

(5 GHz)

monopole port
Creation of a Multipath-Rich Environment

Radio Echoic Chamber (Reverberation Chamber) as a Reference Environment
Handmade Radio Echoic Chamber (Reverberation Chamber)

The chamber is enclosed with 20 aluminum plates (1mx2m plate)
Radio-Echoic Chamber

Creation of an ideal multipath-rich environment

The chamber is enclosed with 20 aluminum plates (1mx2m plate)
Measurement of Propagation Characteristics

5GHz Band Dipole Antennas

Network Analyzer
Measured Propagation Characteristics in frequency and spatial domains
Measured Characteristics of Radio-Echoic Chamber

The characteristics are well represented by an outdoor multipath-rich environment!!
CDF of Received Power for H-H, V-H, and Z-H

Radio Echoic Chamber (Multipath-rich environment)

Rx pol: Horizontal (H)

Received power when Tx power is 0dB [dB]
The largest eigenvalue for multiple polarizations

(measured in a radio echoic chamber)
CDF of Channel Capacity

A: single pol. (1x1)
B: dual-pol. (2x2)
C: tri-pol. (3x3)
D: 3-antenna array (3x3)
**Average channel capacity when using multiple polarizations**

- **Case A**: Single-pol. (V-V: 1x1)
- **Case B**: Dual-pol (V,H-V,H: 2x2)
- **Case C**: Tri-pol (V,H,Z-V,H,Z: 3x3)
- **Case D**: Three single-pol. antennas by three single-pol. antennas (V,V,V-V,V,V: 3x3)
Conclusions

- Tri-polarization antenna, which is one of very compact antennas, showed a nearly the same performance of 3x3 single-pol MIMO array in multipath-rich environment.

- We will evaluate the performance of the antenna in actual environments (both indoors and outdoors).
Thank you very much for your kind attention!