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# Understanding Reliability in Mobile Broadcast

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GLOBAL INFRASTRUCTURE X PROCESS EQUIPMENT X DIAGNOSTIC TOOLS

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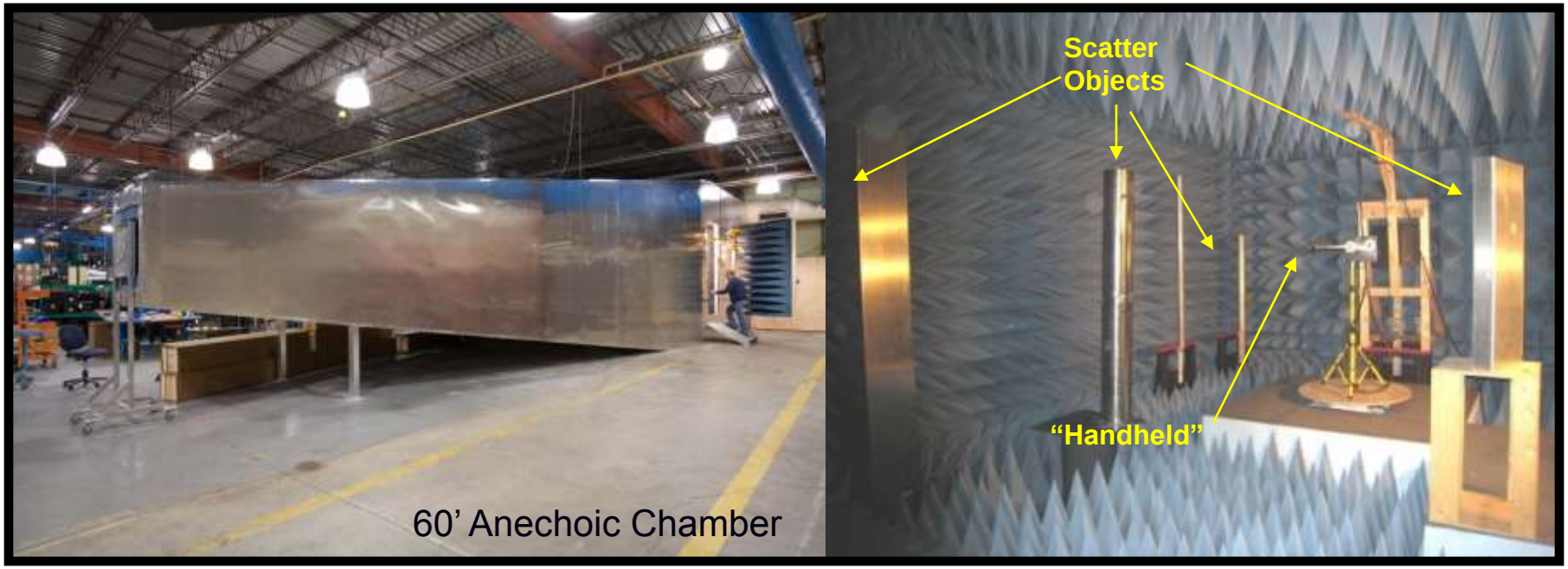
WHERE IDEAS MEET INDUSTRY

## 2008 - 2009 Presentations

## “Polarization Considerations for Mobile TV”


**Presented experimental results showing that transmitting circular polarization to a linearly polarized receiver provided 5 dB of margin improvement over transmitting linear polarization in a depolarized, fading environment**

**Original experiments were performed in an anechoic chamber filled with metal objects to create a scatter environment**




**Experiments were performed at 700 MHz (UHF)**

# Two Most Frequently Asked Questions

***1. "Your experiments were performed in a controlled environment….but what about the real world?"***

***2. "What about VHF?"***

# Voice vs. Video

***What is the difference in reliability expectations between voice and video?***

# Reliability Expectation of Voice

***How does Ruby deal with poor cellular voice service?***

# Reliability Expectation of Voice




**We have been trained to accept poor reliability in voice service**

# Reliability Expectation of Video

***How does Gary deal with poor mobile TV service?***

# Reliability Expectation of Video

Options

Just accept it

Probably not. Video service is a luxury.

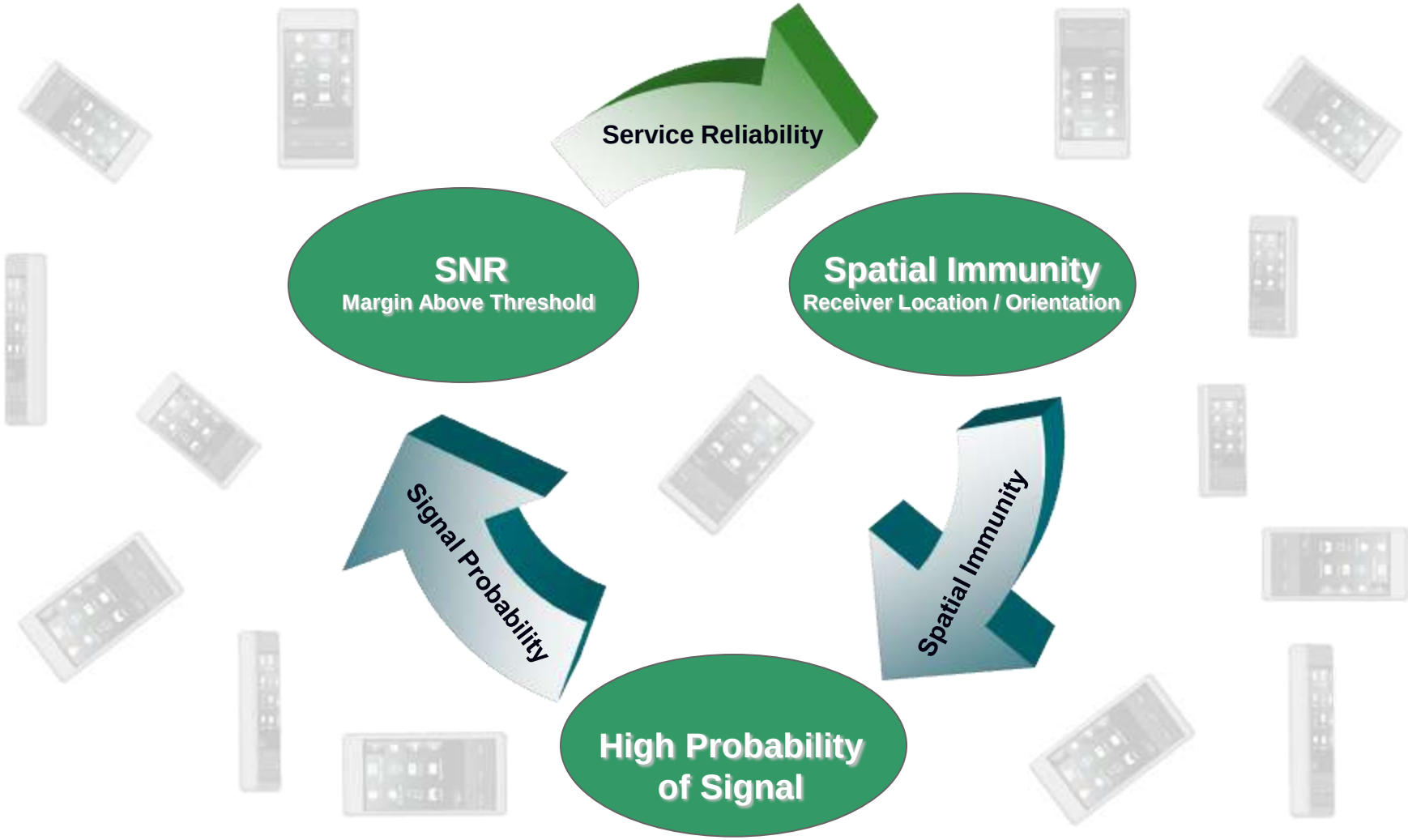
Discontinue service

Most likely

Change Providers

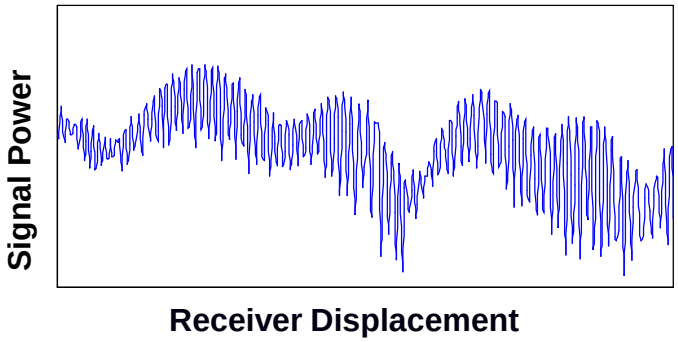
Maybe

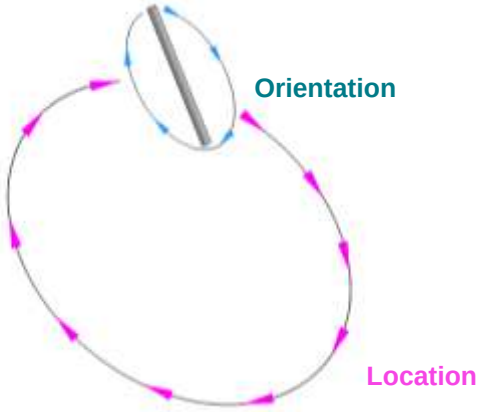
# The Key to the Success of Mobile TV



# New Experiment in Outdoor Environments

**Both polarization mismatch and fading (multipath) produce variability in the signal as the receiver changes orientation and location**




**Can the choice of transmit polarization increase the reliability of mobile TV service?**

Open Areas | Wooded Areas | Office Building | House | Small Vehicle

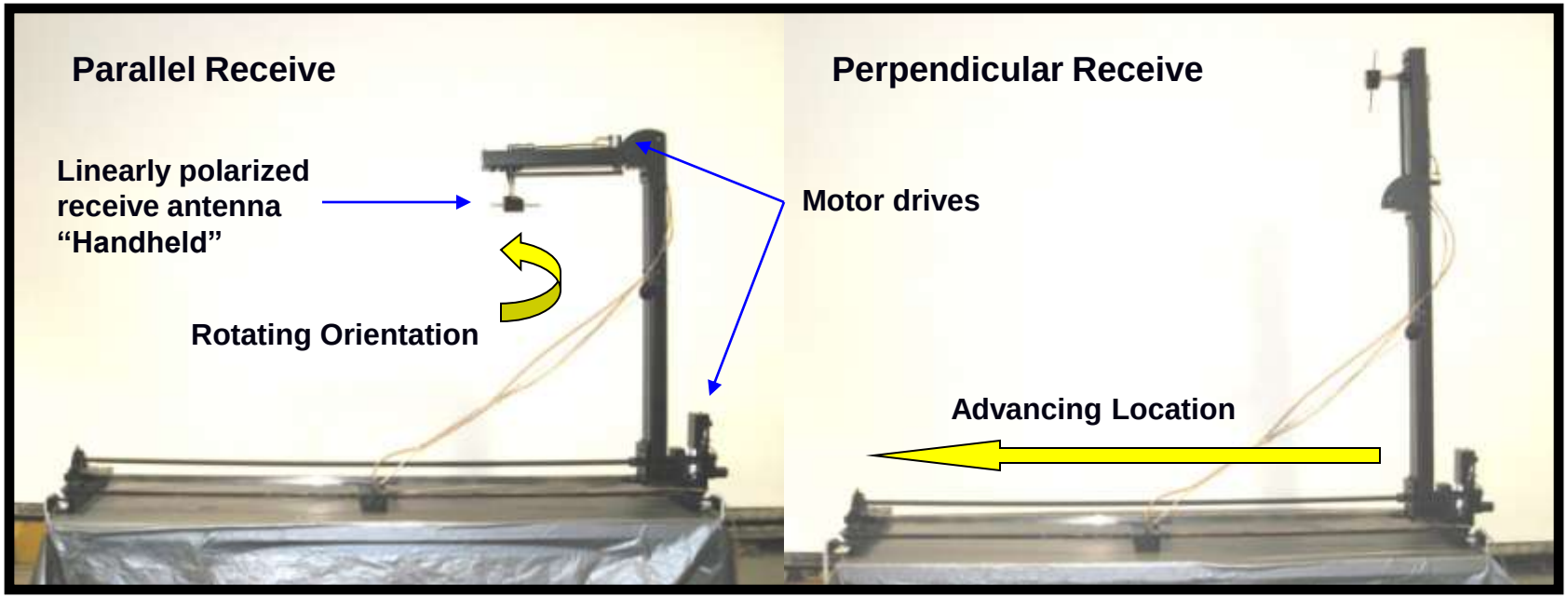
# Experiment Procedure and Analysis – Step 1

**Transmit horizontal, vertical and circular polarization from the same location and with the same azimuth and elevation patterns with equal ERP**


**Frequency 700 MHz**

# Experiment Procedure and Analysis – Step 2

**Measure received signal power versus receiver orientation and location**



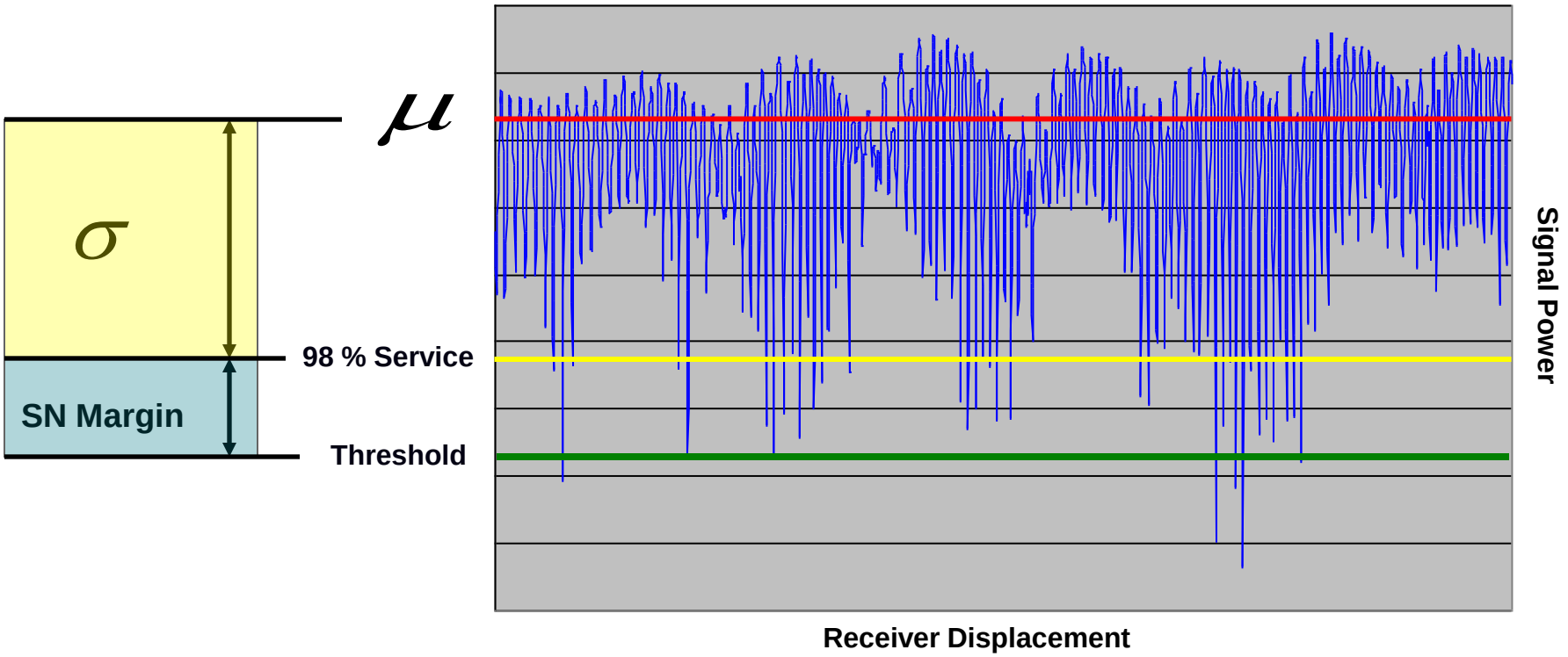

**"Ralph" Rotating Advancing Linearly Polarized Handheld**

# Experiment Procedure and Analysis – Step 3

**Collected over 2000 data points in each run with over 600K data points in all**

**Calculate the mean value of the signal strength $\mu$**

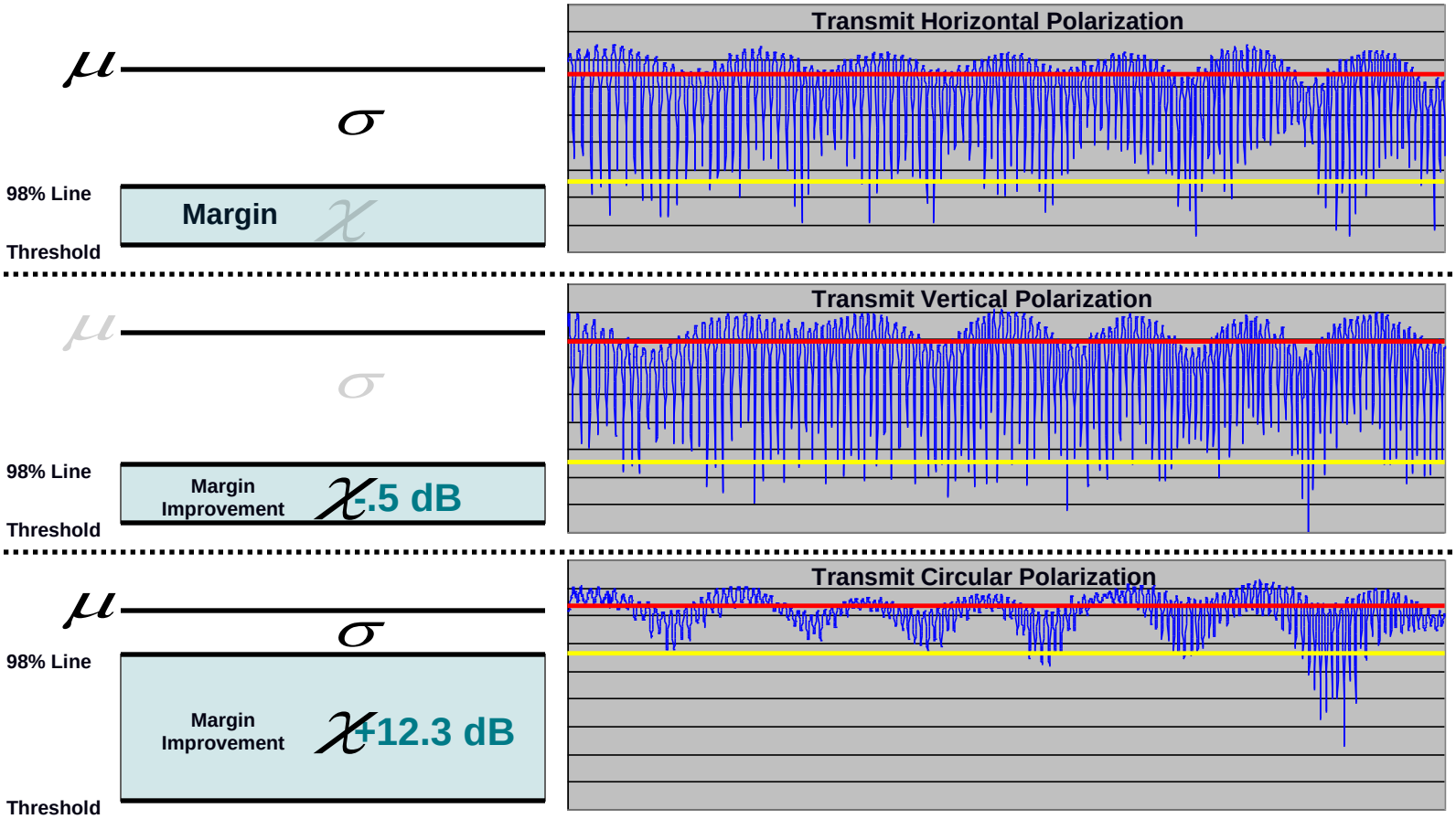
**Calculate the variability spread $\sigma$ between the mean and a desired probability of service line**




**Decreasing the variability and/or increasing the mean value of the signal strength of the received signal is exactly the same as increasing the SN margin**

# Experiment Procedure and Analysis – Step 4

**Compare the margin improvement of vertical and circular polarization relative to horizontal polarization.**



# Data Collection – Step 5

Performed the measurement procedure in multiple locations within the 5 different environments in both perpendicular and parallel receive modes

House

Office Building

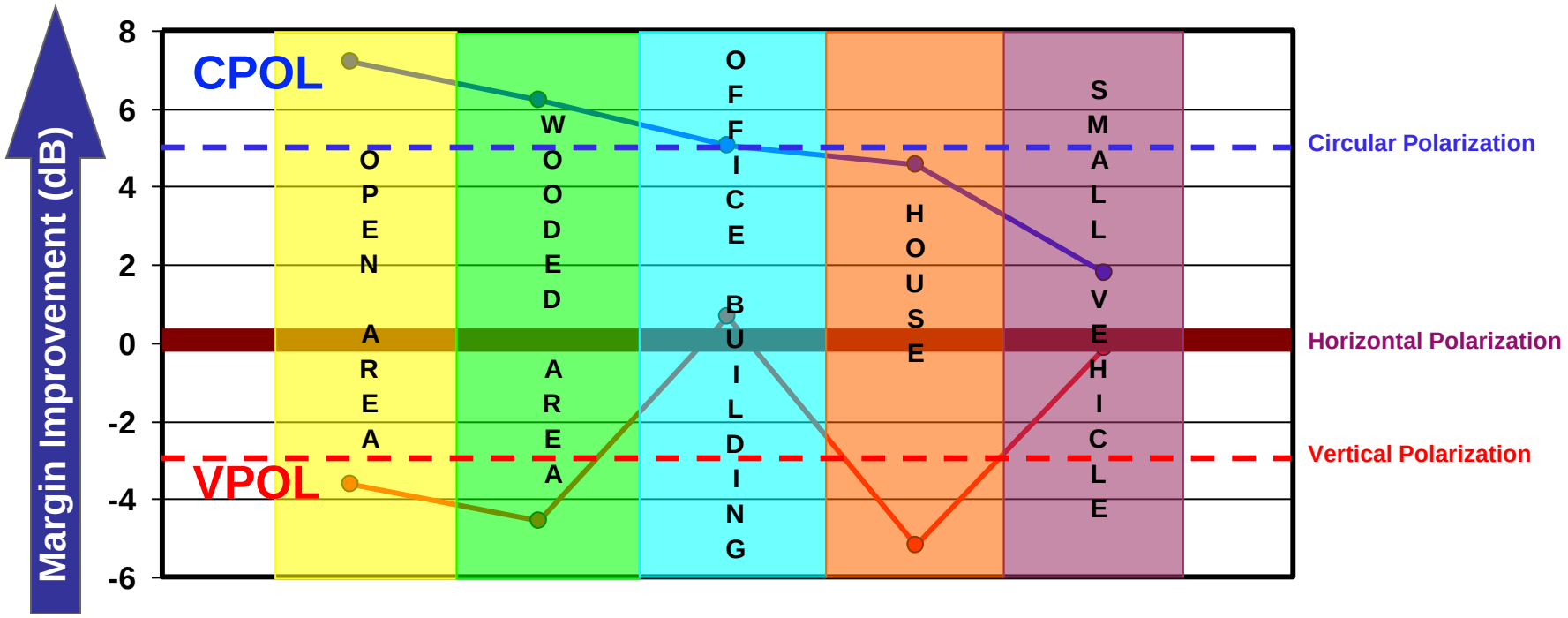
Open Areas

Small Vehicle


Wooded Areas

Averaged all the measurement runs for CPOL, HPOL and VPOL transmission within each environment type

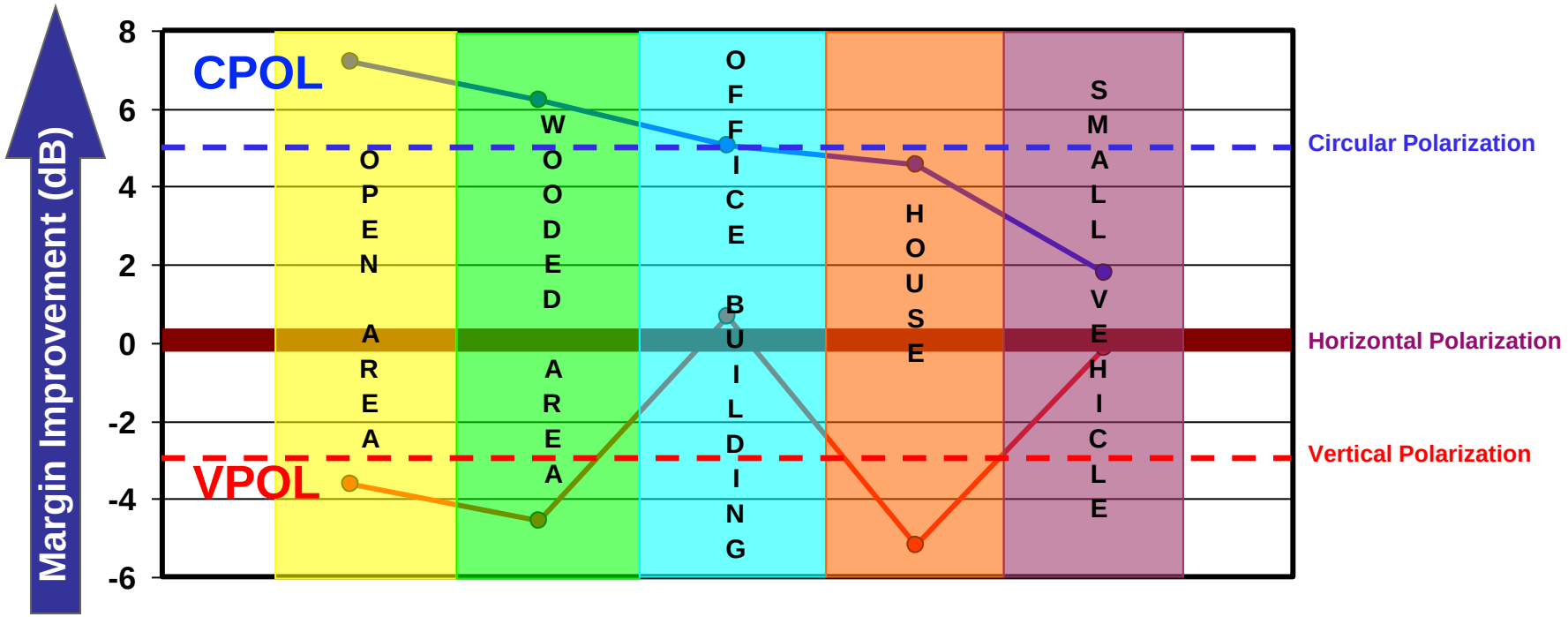
# Results Summary UHF




- On average, circular polarization offers 5 dB margin improvement over horizontal polarization
- On average, circular polarization offers 7.5 dB margin improvement over vertical polarization

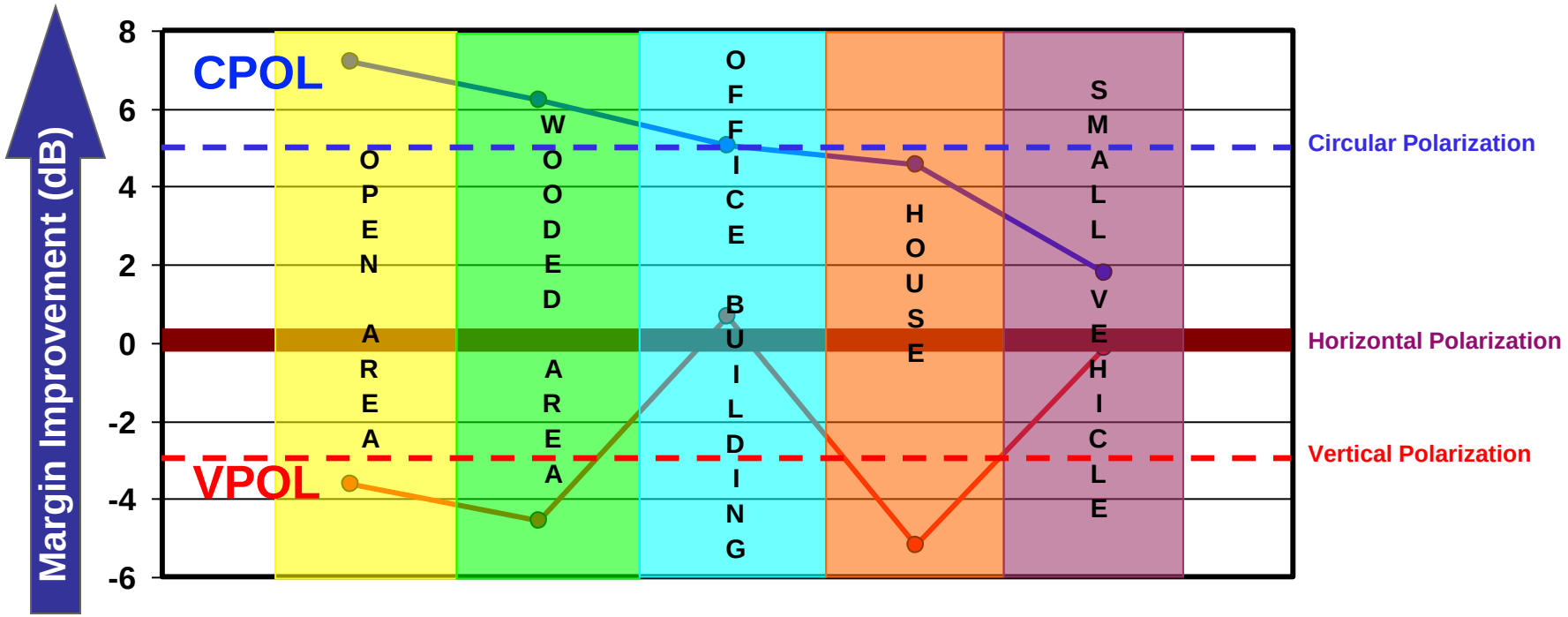
## Frequency 700 MHz

# Observations UHF




1. **Why is VPOL much worse than HPOL?**
   - VPOL is more susceptible to multipath than HPOL
   - Heavy depolarization in the parallel receive mode

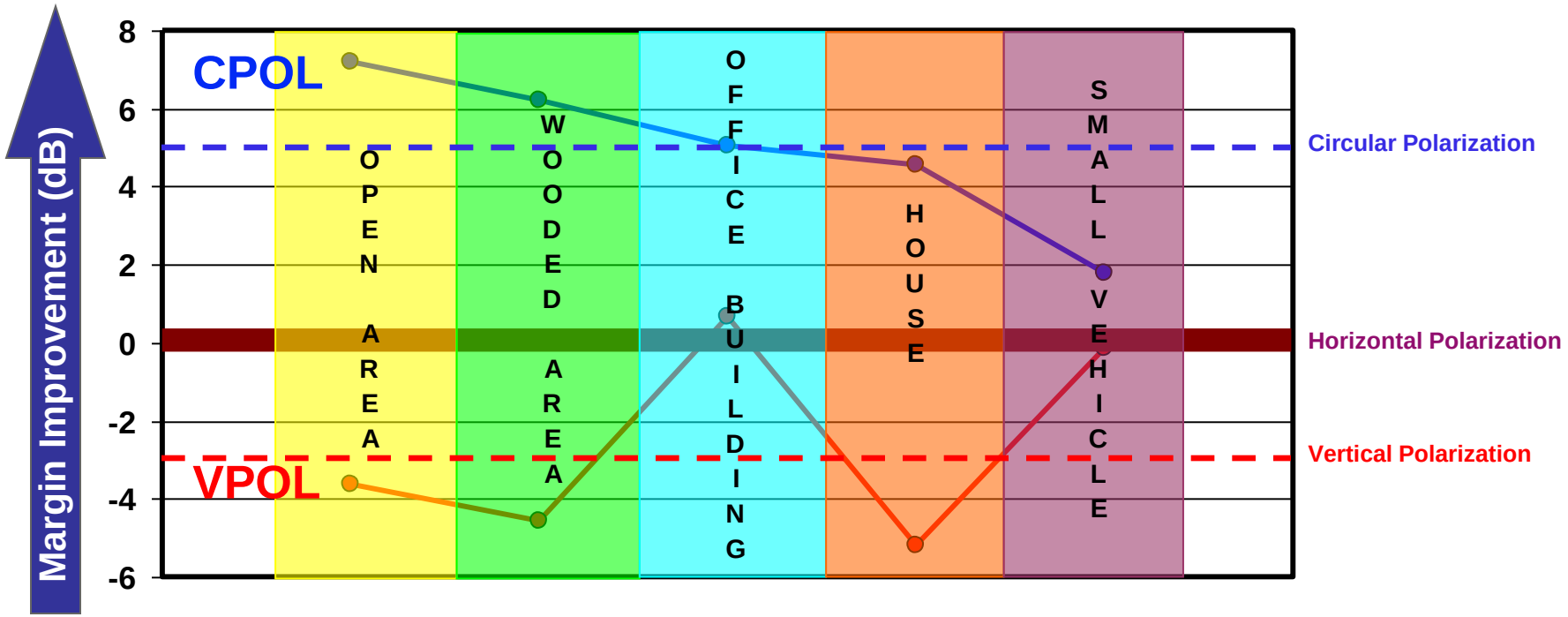
# Observations UHF




2. **Why are HPOL and VPOL similar in the office and vehicle environments?**

   - **These represent heavy small scale fading environments which are very depolarized**
   - **HPOL and VPOL become indistinguishable**

# Observations UHF




**3. If these environments are so depolarized, then why is CPOL so much better than HPOL and VPOL?**

- Linear polarization scatters into randomly polarized waves creating constructive and destructive interference. Destructive interference creates hole or gaps in the coverage.
- CPOL is made up of two orthogonal polarizations time shifted by 90 degrees. The odds of both polarizations destructively interfering at the same time and same location is much smaller than a single polarization.

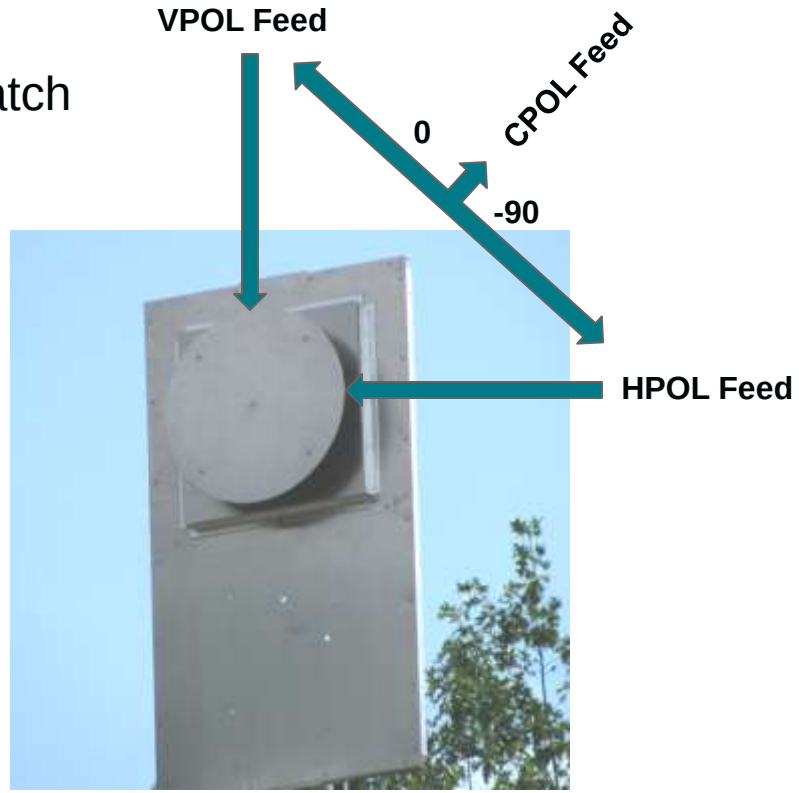
**Circular polarization fills in the gaps or holes in coverage**

# What about VHF?

# Extend experiment to VHF

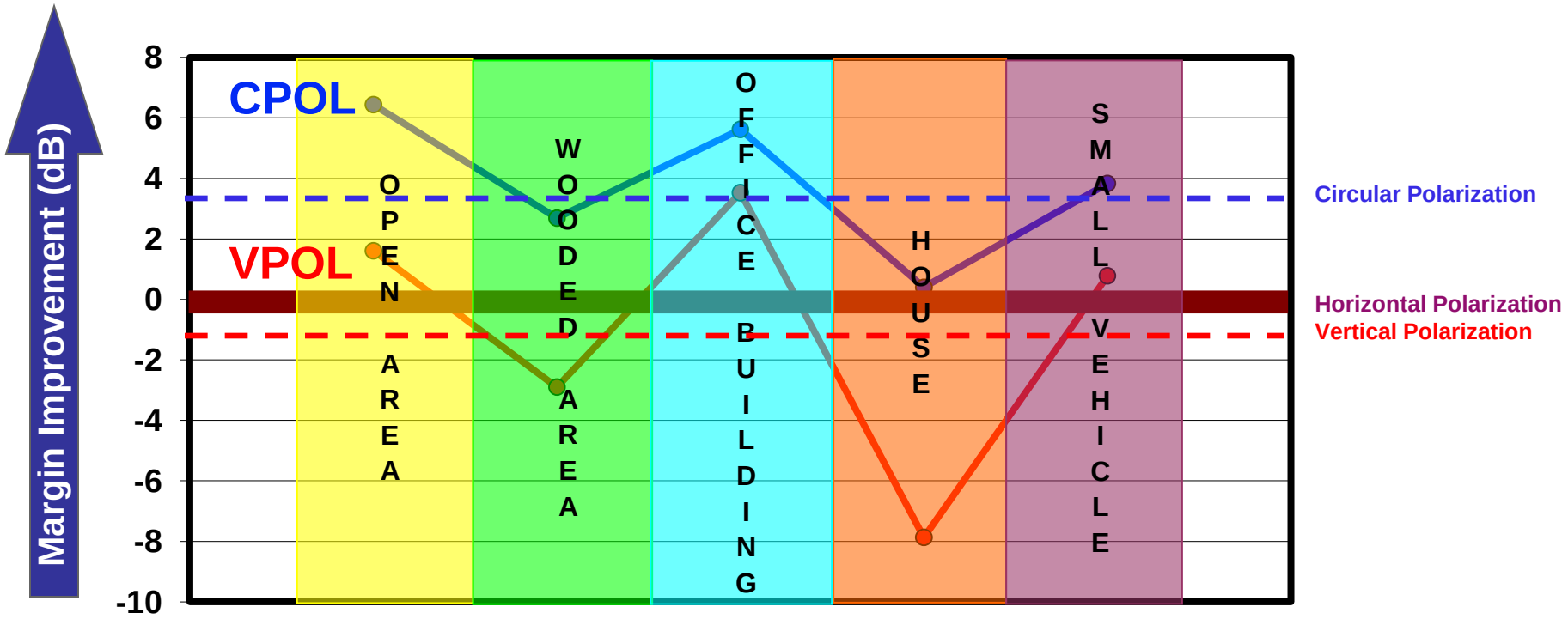
Same measurement procedure
Same receive setup – “Ralph”
Same transmit location
Same receive locations
Change transmit frequency to 210 MHz
Change transmit antenna to a VHF dual feed patch


Frequency 700 MHz




Frequency 210 MHz

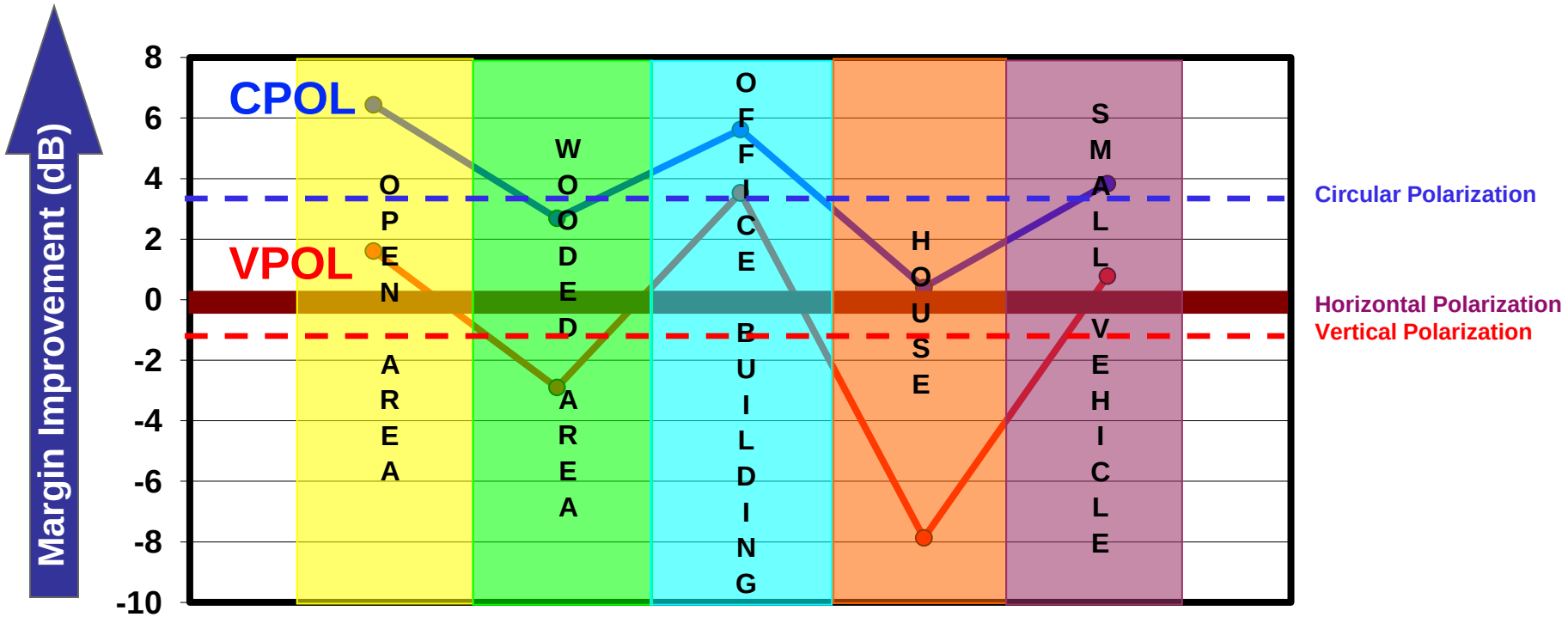
# Results Summary VHF




- On average, circular polarization offers 3.5 dB margin improvement over horizontal polarization
- On average, circular polarization offers 4.5 dB margin improvement over vertical polarization

## Frequency 210 MHz

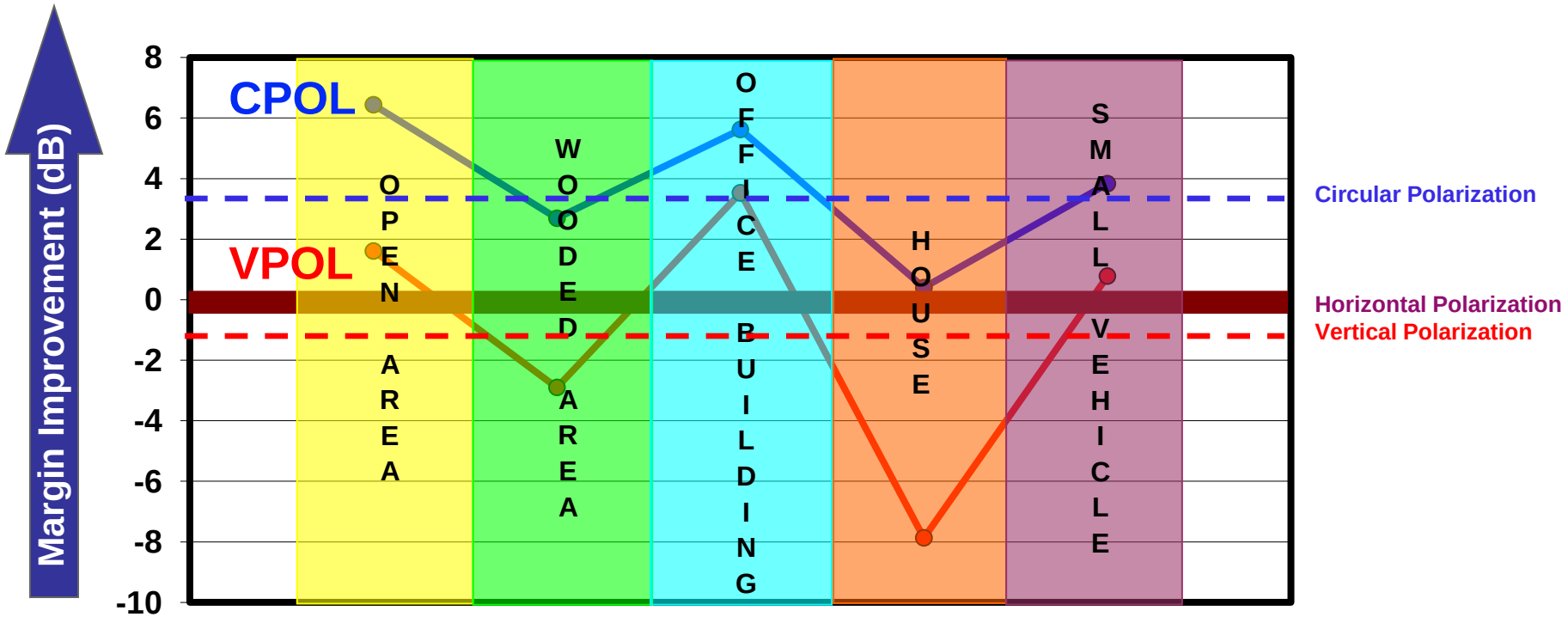
# Observations VHF




1. **Why is there little difference between HPOL and VPOL at VHF?**

   - The receive antenna is electrically small at VHF which provides less polarization discrimination than it does at UHF. As the receive antenna approaches a point source, it becomes "omni polarized" .
   - HPOL and VPOL will converge.

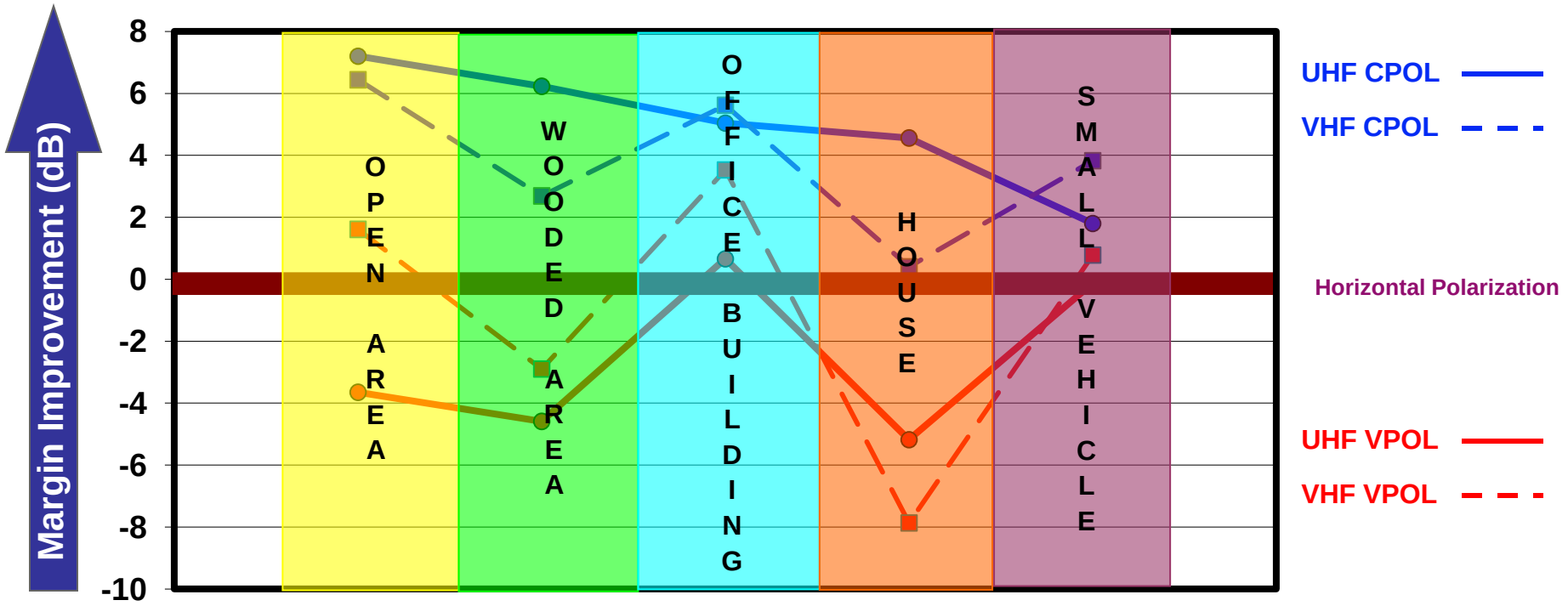
# Observations VHF




2. **If VPOL and HPOL are converging, then why is CPOL still 3.5 dB better?**

- Linear polarization is prone to holes and gaps in coverage
- CPOL fills in these holes and gaps

# Observations VHF




3. **Why does the VHF CPOL follow the VPOL contour?**

   - The receive antenna at VHF does not suffer from polarization mismatch leaving multipath as the main contributor to the variability.
   - Since VPOL is more susceptible to multipath than HPOL, then it only makes sense that the VPOL will be the dominating component in the CPOL's variability.

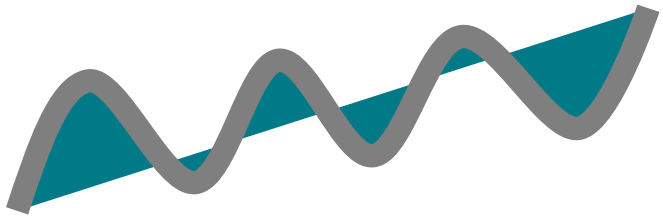
# Observations VHF

- On a small handheld receiver, VHF provides
  - Less polarization discrimination
  - Greater orientational immunity
  - "Omni Polarized"
  - On average circular polarization provided 3.5 dB of margin improvement over horizontal polarization

**Great news for VHF….right?**

# Compare UHF and VHF

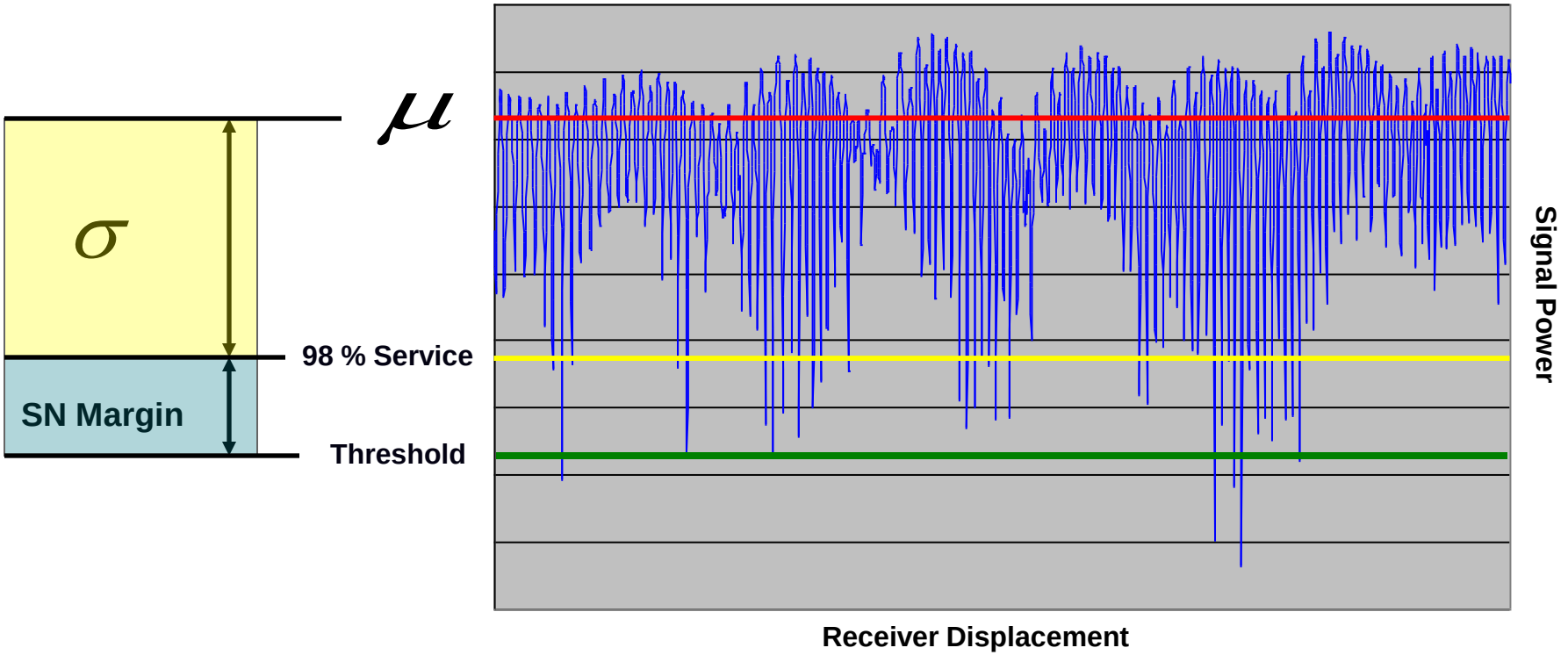
## for mobile service using a small linearly polarized handheld

# Recall Margin = Reliability

Two methods to increase margin

1. Decrease the variability in signal
2. Increase the mean signal strength



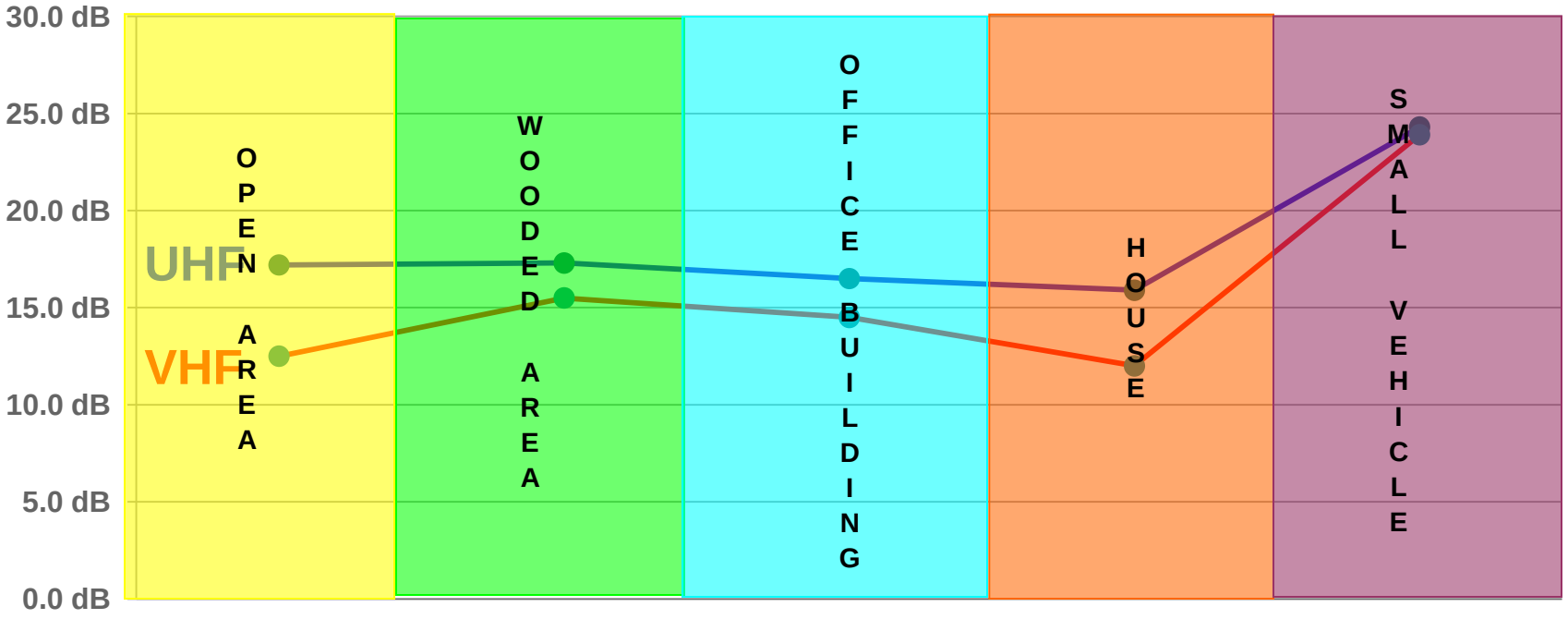

**Compare the average variability and mean signal strengths of VHF and UHF in fading depolarized environments**

# Average Variability in Signal UHF vs. VHF

**Average Variability**

| | UHF | VHF |
|---|---|---|
| Open | 17.2 dB | 12.5 dB |
| Woods | 17.3 dB | 15.5 dB |
| Office | 16.5 dB | 14.5 dB |
| House | 15.9 dB | 12.0 dB |
| Vehicle | 24.3 dB | 23.9 dB |
| Avg | 18.2 dB | 15.7 dB |

- Recall the two components that produce the variability
  - Polarization mismatch
  - Fading
- The "omni polarized" characteristics of the receiver should provide less variability at VHF then at UHF




***VHF has 2.5 dB less variability than UHF***

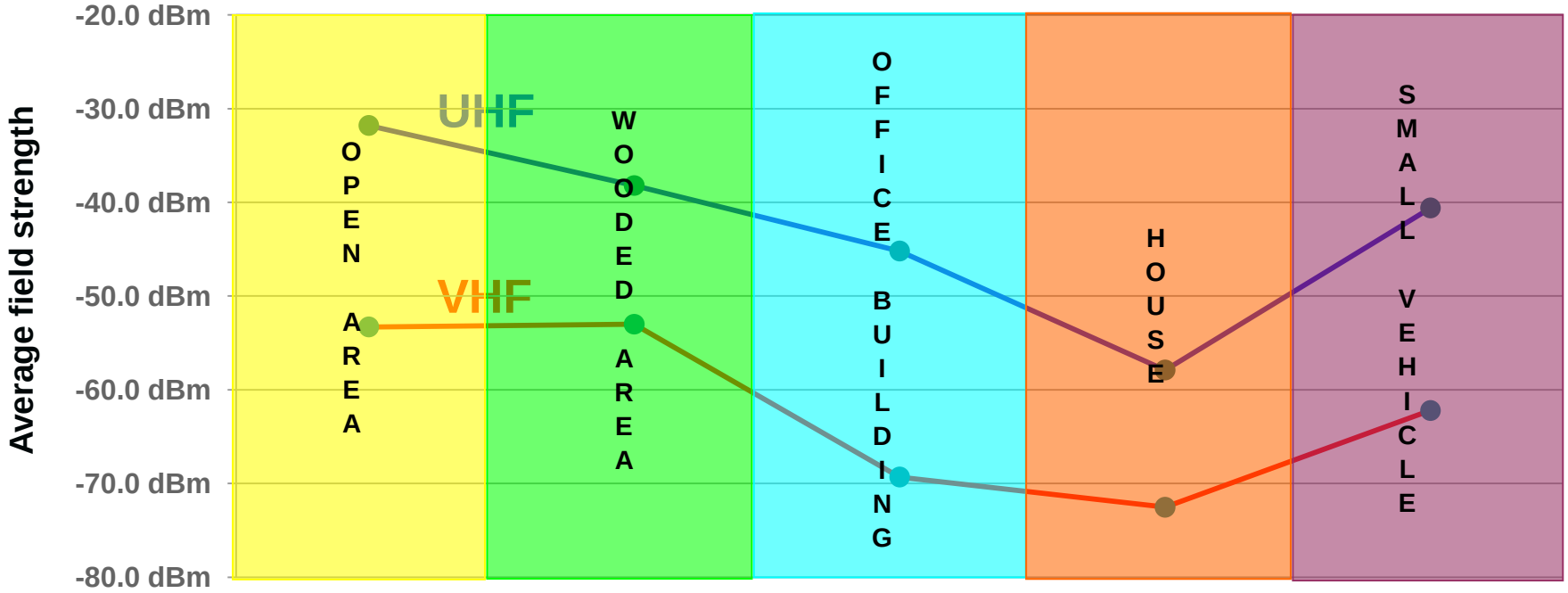
# Average Received Signal Strength UHF vs. VHF

## Link Budget

| | VHF | UHF |
|---|---|---|
| Antenna Gain | -3.1 dB | 0.0 dB |
| Tx Power | -4.0 dB | 0.0 dB |
| Tx Cable | 3.6 dB | 0.0 dB |
| Rx Cable | 0.5 dB | 0.0 dB |
| Rx Ant. VSWR | -9.5 dB | 0.0 dB |
| Free space loss | 9.8 dB | 0.0 dB |
| Adjustment Factor | -2.7 dB | 0.0 dB |

## Average field strength

| | UHF | VHF | Adjusted VHF |
|---|---|---|---|
| Open | -31.8 dBm | -56.0 dBm | -53.3 dBm |
| Woods | -38.2 dBm | -55.7 dBm | -53.0 dBm |
| Office | -45.2 dBm | -72.0 dBm | -69.3 dBm |
| House | -57.9 dBm | -75.2 dBm | -72.5 dBm |
| Vehicle | -40.6 dBm | -64.9 dBm | -62.2 dBm |
| Avg | -42.7 dBm | -64.8 dBm | -62.1 dBm |




***VHF has 19.4 dB less average signal strength than UHF***

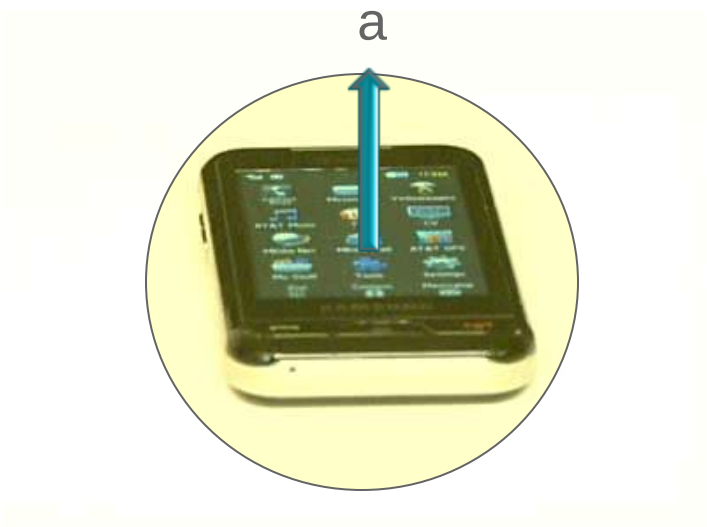
# Wheeler Limit

Harold Wheeler defined the fundamental limitations of electrically small antennas based on their size

Electrically small antenna – max dimension $\leq \dfrac{\lambda}{2\pi}$ $\approx 3''$ **UHF** $\approx 8.5''$ **VHF**

Radiansphere

This is the space occupied mainly by stored electromagnetic energy




Max power factor $\rho_{\max} = (ka)^3$

a = antenna volume radius

$$k = \frac{2\pi}{\lambda}$$

# Wheeler Limit

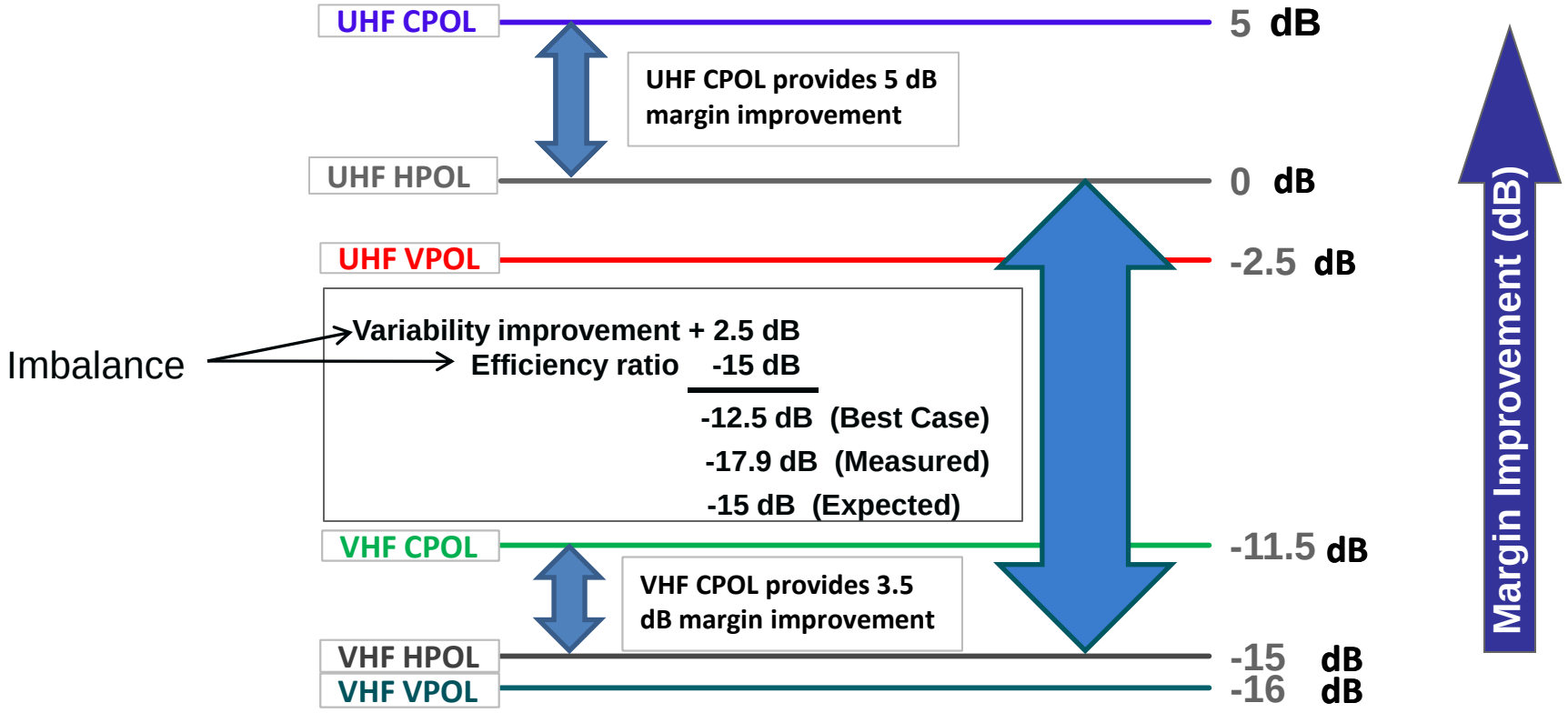
Solve for the max power ratio difference between 210 MHz and 700 MHz

$$\frac{\rho_v}{\rho_u} = 10\log\left[\frac{\left(\frac{2\pi}{\lambda_v}a\right)^3}{\left(\frac{2\pi}{\lambda_u}a\right)^3}\right] = 10\log\left(\left(\frac{\lambda_u}{\lambda_v}\right)^3\right) \approx -15dB$$

**Wheeler limit dictates the best VHF/UHF receive ratio of an electrically small antenna will be -15 dB**

# Summary

Average relative margin improvement of transmitting horizontal, vertical and circular polarization at VHF and UHF frequency to an electrically small linearly polarized receiver in fading depolarized environments



# Conclusion

## Bottom Line……

- Reliability is the key to the success of mobile TV
- Margin = Reliability in mobile services
- For UHF frequencies, transmitting circular polarization will provide a more reliable mobile service than linear polarization
- Reliable mobile service to a small handheld receiver may not be practical at VHF frequencies

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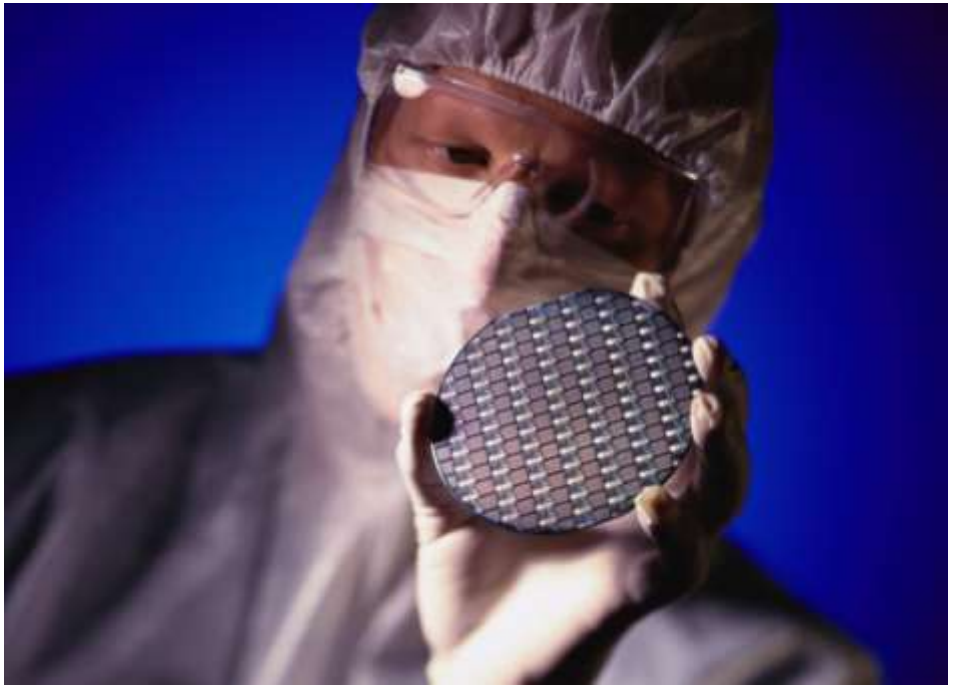
# "Even though the world is obsessed with miniaturization, antennas will remain immune"



## Thank You