Secure Pairing of Wireless Devices by Multiple Antenna Diversity

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Ubiquitous Wireless Devices

Most of these devices require ad-hoc connections!

Wi-Fi Direct

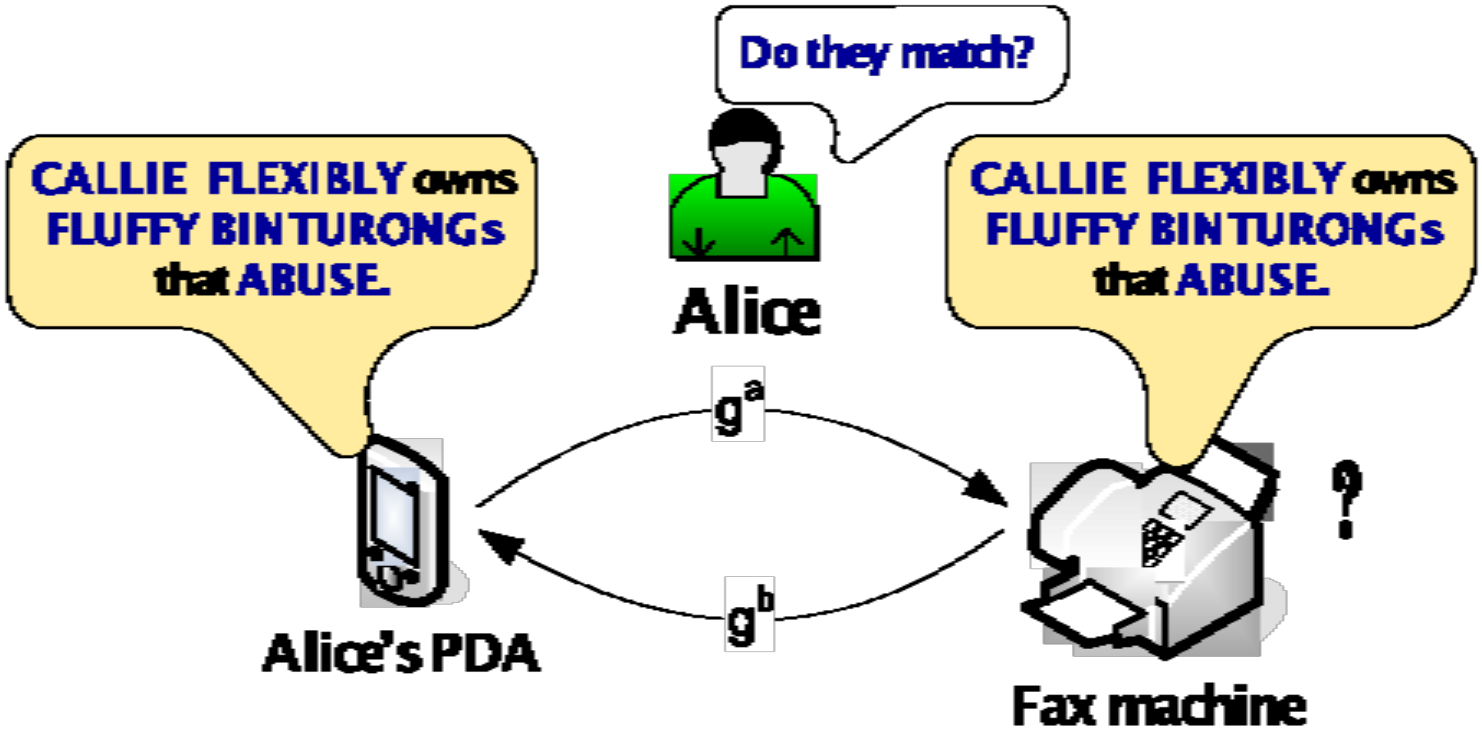
- Allows peer-to-peer Wi-Fi connection (without AP)
- Requires no new hardware
- Specification and certified devices are coming soon

Secure Device Pairing

- Bootstrap secure communication between two devices.
- Common approach: shared PIN code
- Problems
  - Many devices have no keyboard (so they hardcode secrets)
  - Potential user error and vulnerability
- Solution: using out-of-band (OOB) channels

Visual Channel (Seeing is Believing)

Acoustic Channel (Loud and Clear)



Motion Channel (Shake well before use)

Limitations of OOB Channels

- OOB channels are not ubiquitous on all devices
- Some OOB channels are vulnerable to attacks (Halevi etc. CCS ’10)

Desirable Device Pairing Scheme

- Use no out-of-band channel
- Does NOT require the user to
  - Enter secrets (simplify user tasks), or
  - Verify secrets (avoid user mistakes)

Our scheme: Good Neighbor

- Use the wireless channel
- Securely pair devices based on proximity

Why not using Distance-bounding Protocols

- Cryptographic protocol that allows verifier V to establish an upper bound on physical distance to a prover P.

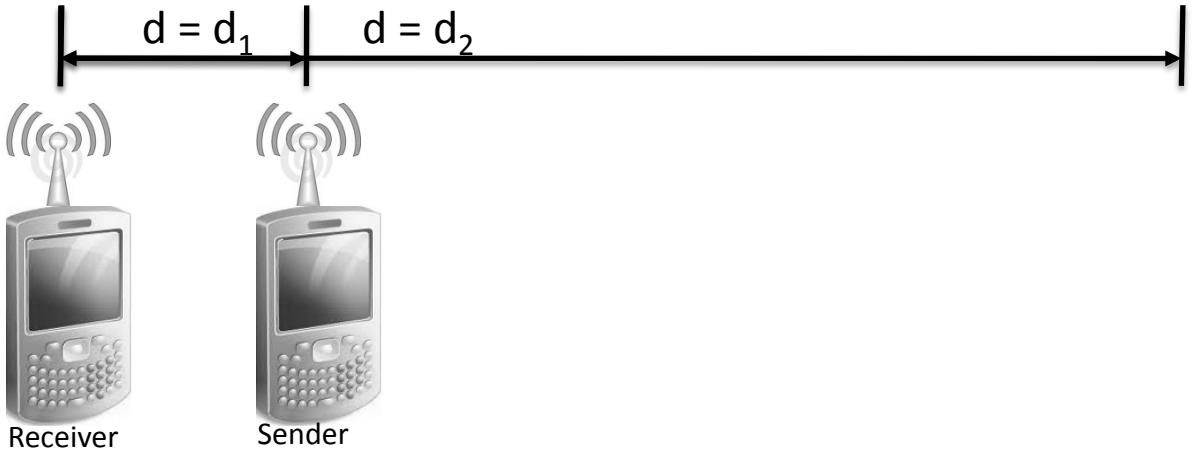
- Based on the fact that electro-magnetic waves travel nearly at the speed of light, but cannot travel faster
- Rely on a rapid bit exchange and require precise clocks to measure light-speed messages

Threat model

- Attackers can
  - Have powerful antennas
  - Have exact copies of the pairing devices
  - Know the exact location of the pairing devices
- Attackers can NOT
  - Come in close proximity of the receiver (Eg. less than 20cm).
  - Compromise the pairing devices.
  - Jam the channel

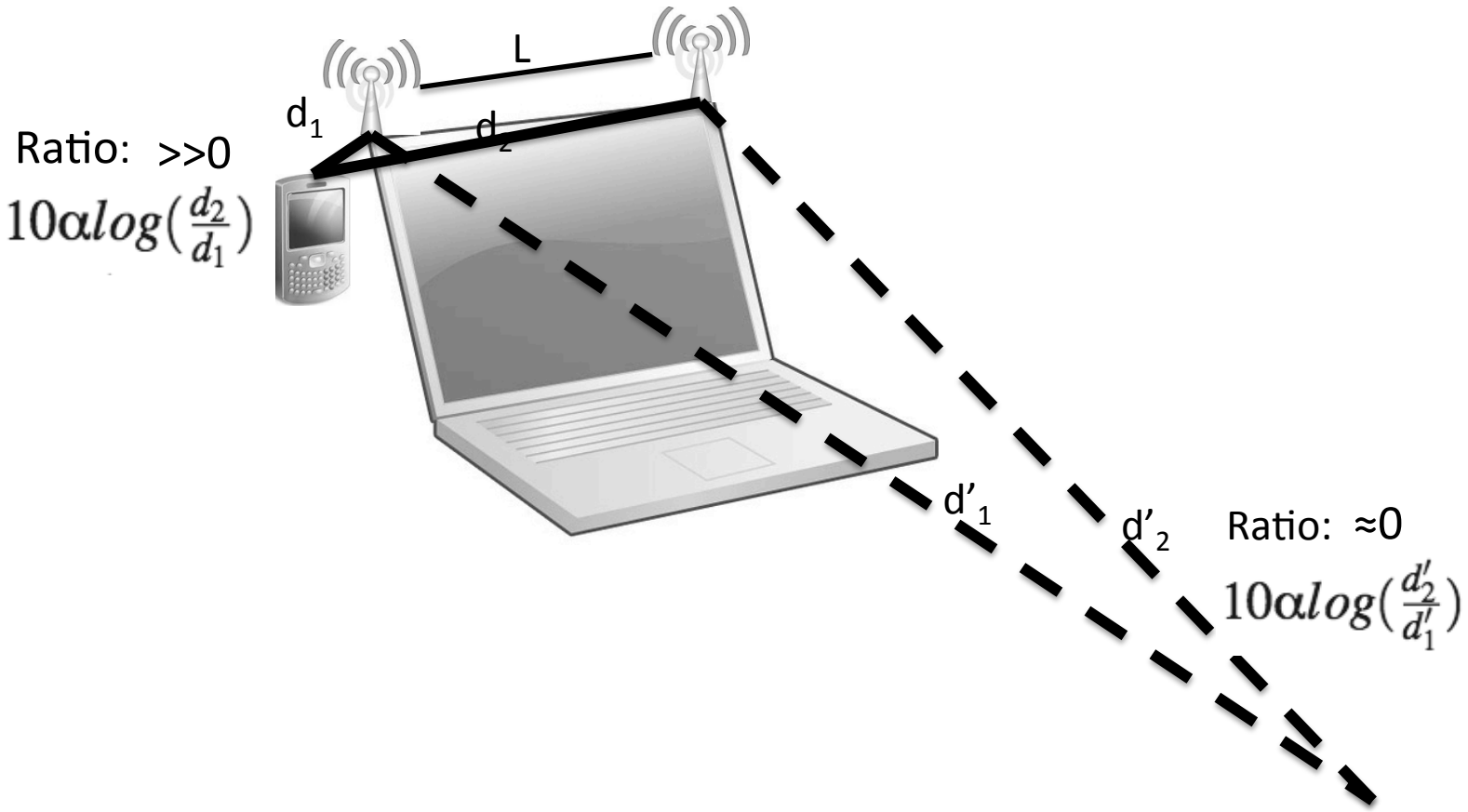
Naïve Approach: Inferring proximity by RSS

$$P_r[dBm] = P_0 - 10\alpha log(\frac{d}{d_0}) + X_\sigma$$

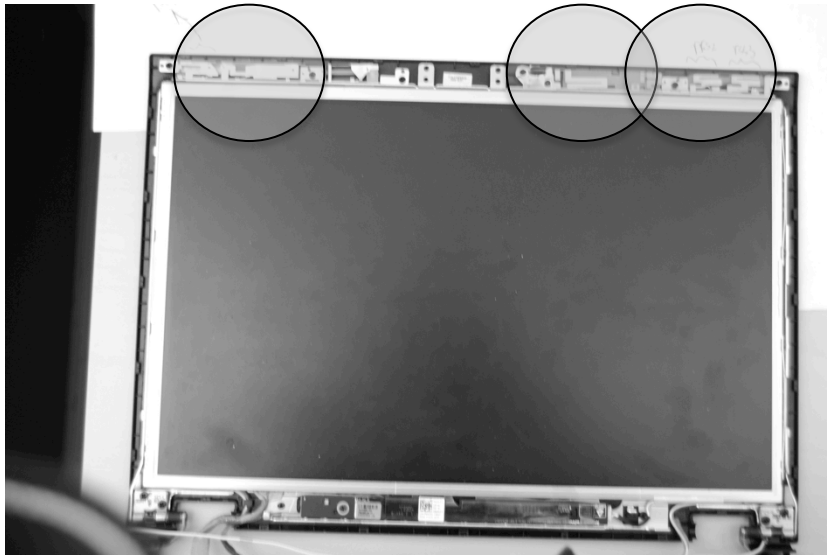


Changing P_0

Improvement: Inferring proximity by RSS ratio

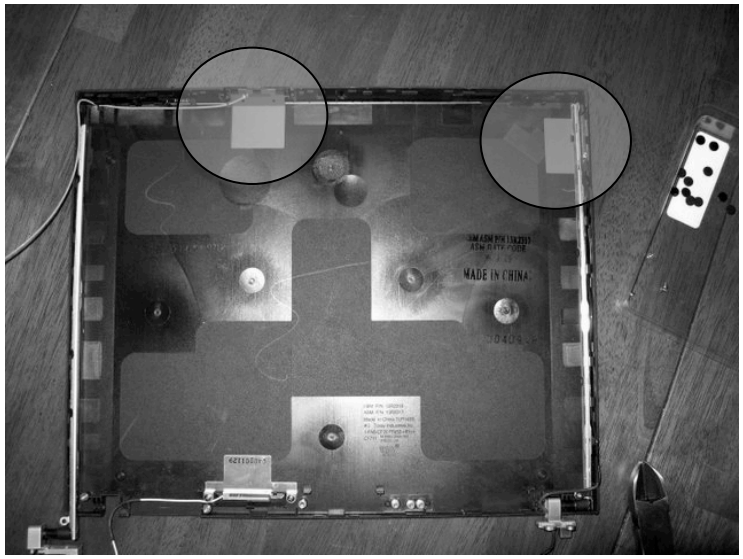


Antenna Diversity and IEEE 802.11n MIMO



Dell e5400 (MIMO antennas)

- MIMO
- Spatial multiplexing (From 54Mbps to 600 Mbps)



IBM T42P (Antennas diversity)

- Spatial diversity: to improve the quality and reliability of a wireless link

Practical Problem: Unstable RSS Values

- Problem:
  - RSS values may fluctuate
- Solution:
  - Sender (S) sends a series of packets
  - Receiver (R) calculates the mean and deviation of the RSS values

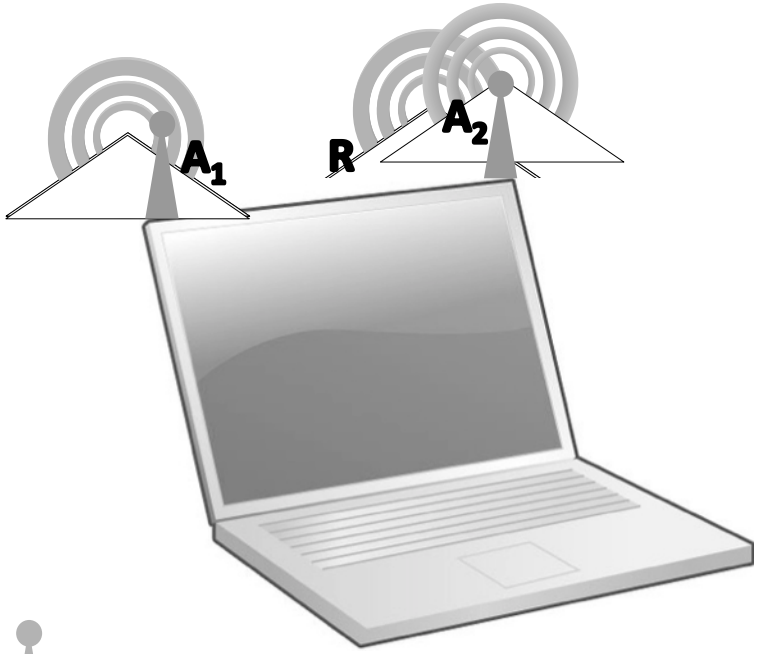
Practical Problem: RSS saturation

- Problem:
  - RSS value saturates when the signal is too strong or too weak.
- Solution: (power probing)
  - S sends probing packets with different transmission power levels
  - R chooses the optimal power level that results in the largest RSS ratio

Practical Problem: Automatic Rate Adaptation

- Problem:
  - Inconsistent RSS values if the Automatic Rate Adaptation feature is enabled.
- Solution:
  - Disable Automatic Rate Adaptation.

Final scheme



S R

Move S close to A_1 of R

AuthRequest()

AuthResponse(K_R)

PowerQuery(l,n)

PowerResponse(l)

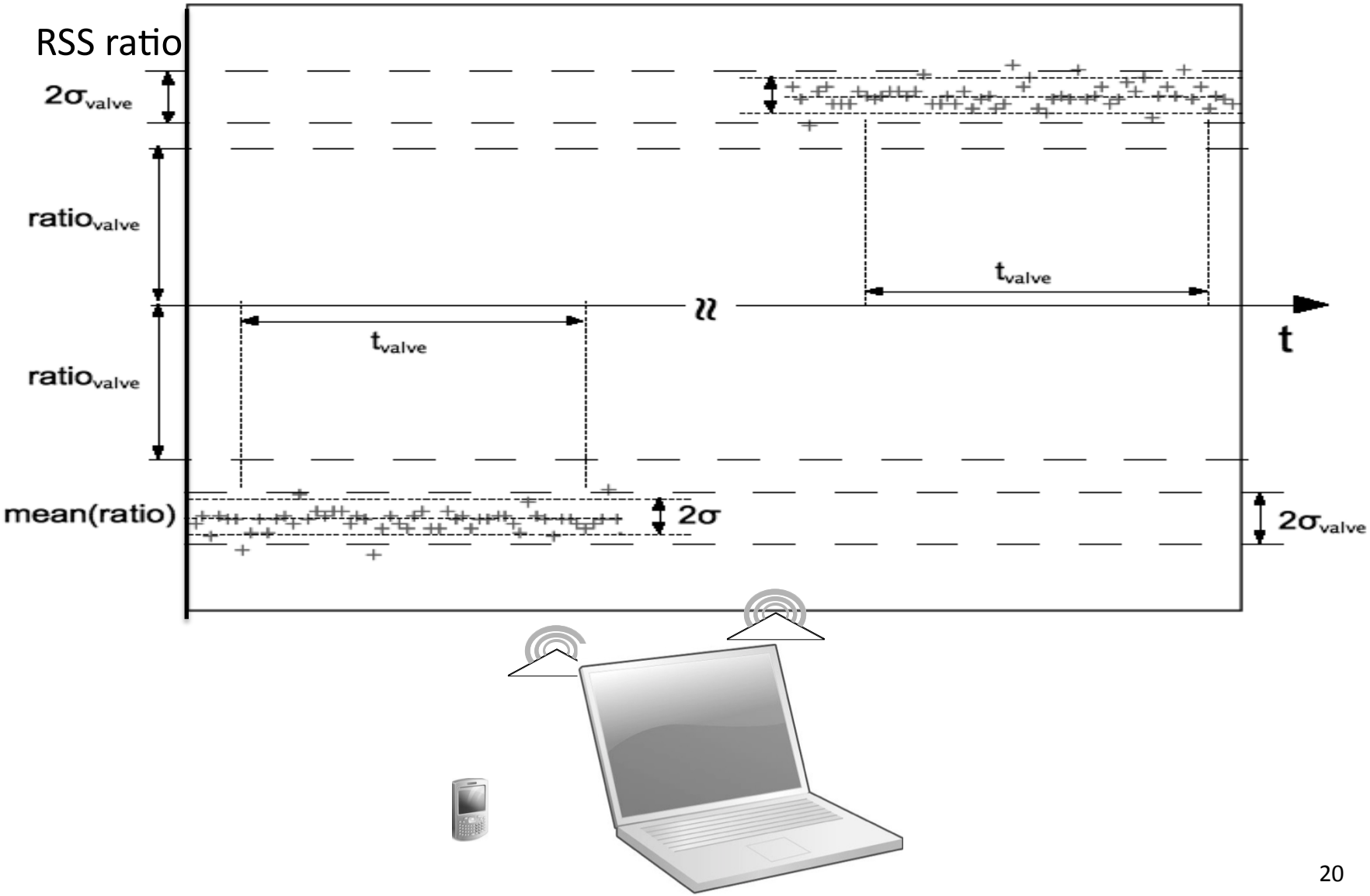
RSSMeasure(E_{KR}(k))

Move S close to A_2 of R

RSSMeasure(E_{KR}(k))

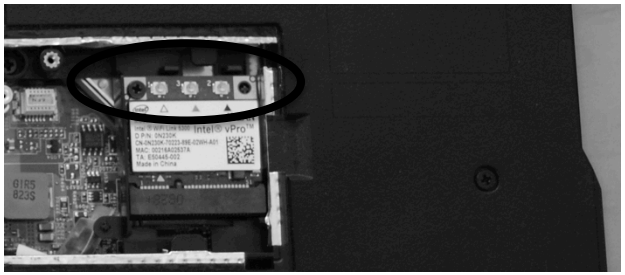
Success()

Typical RSS ratio of successful device pairing



Antennas used in our experiments

Type 1: internal antennas for Dell E5400 laptop

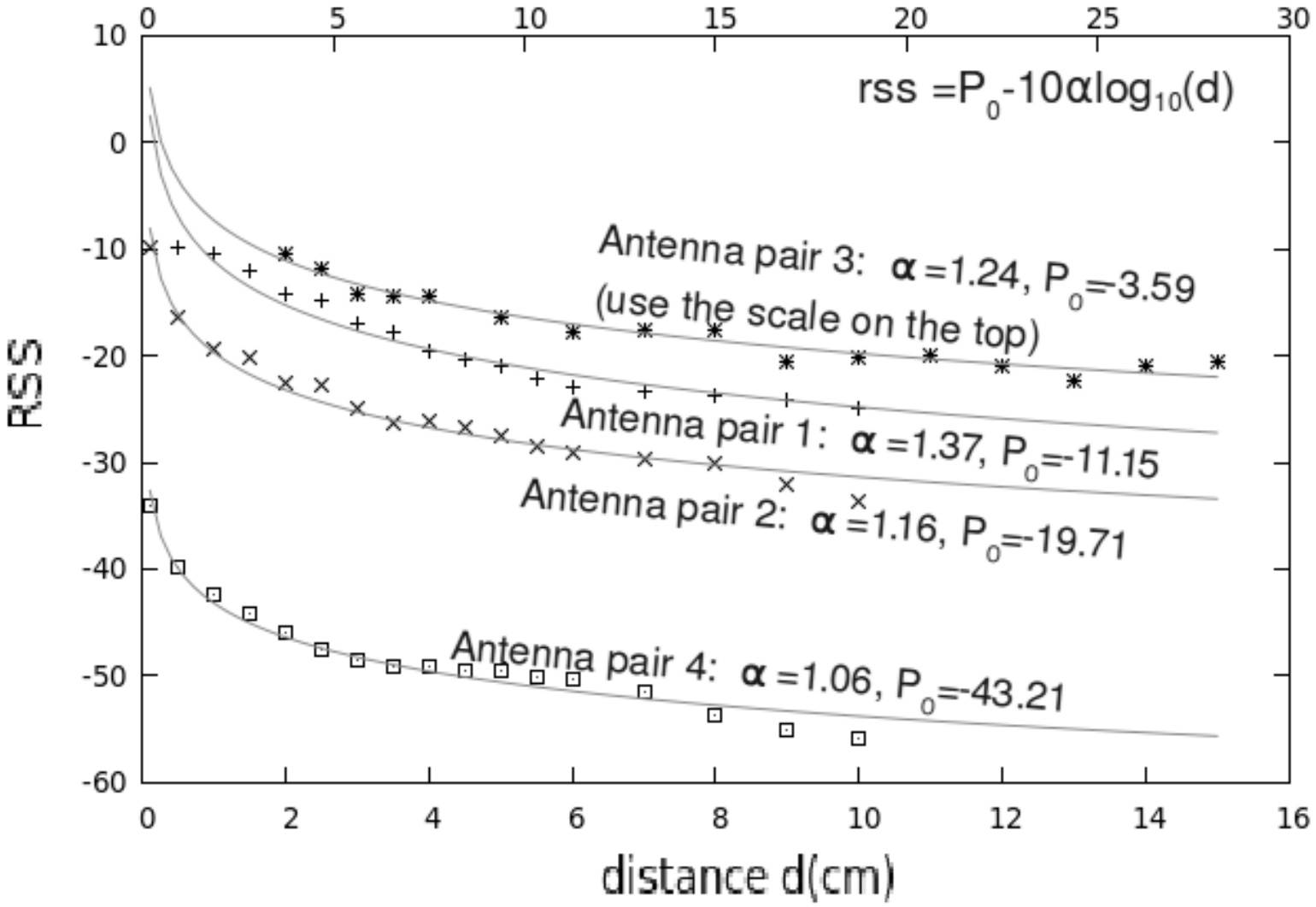


Type 4: Dipole antenna

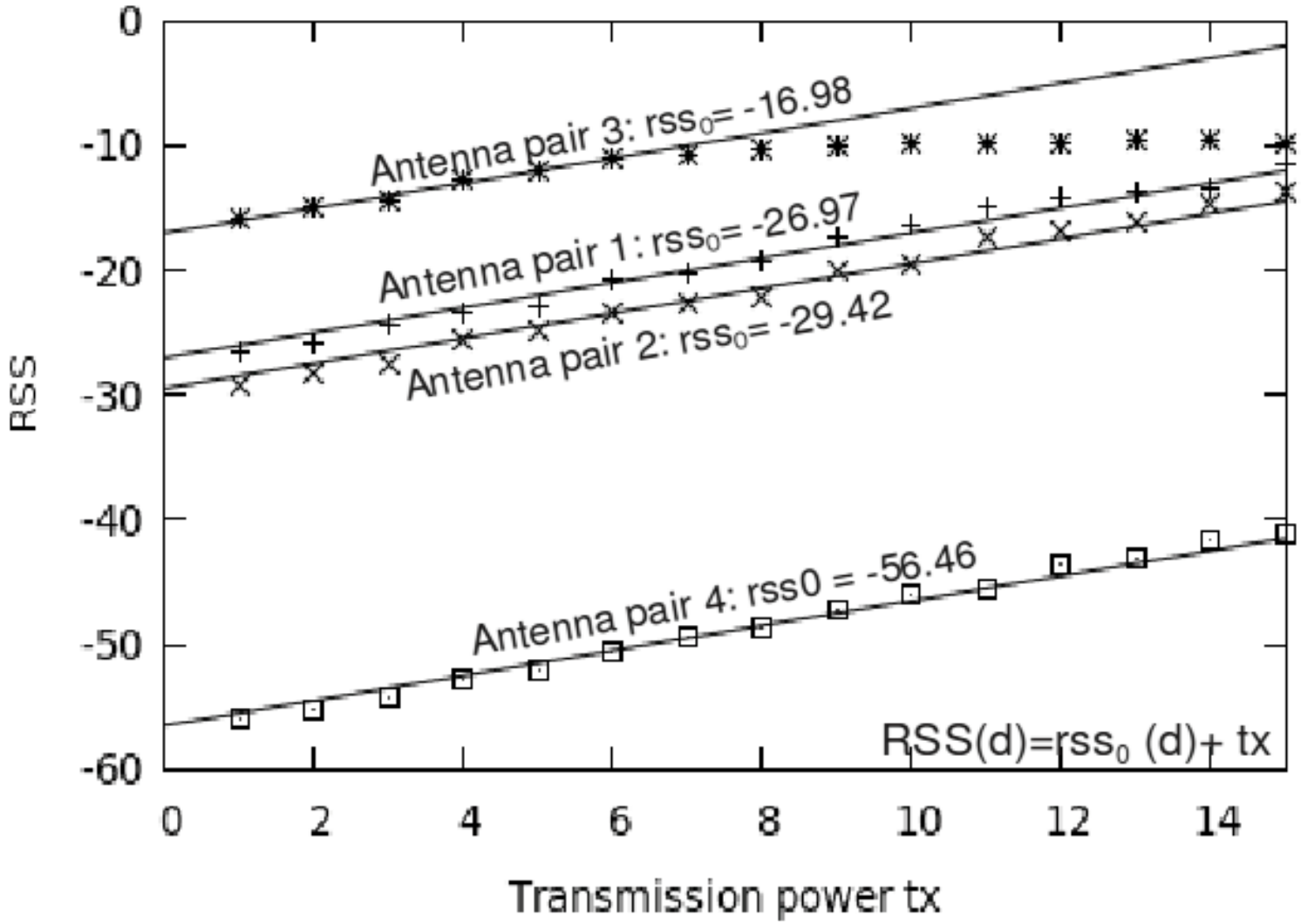
Type 2: antennas for laptop mini PCI cards

Type 3: RP-SMA (f) socket

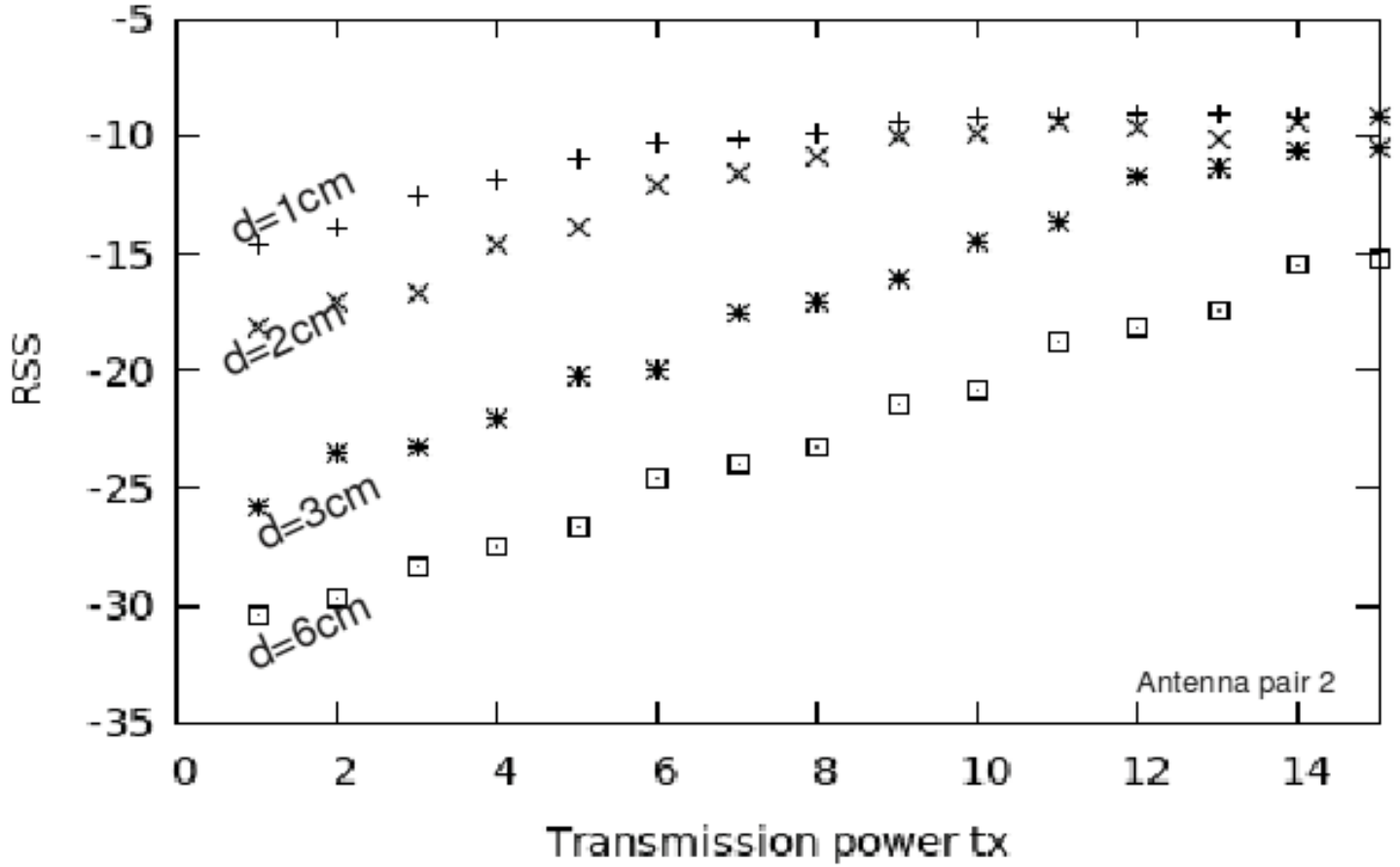
Logarithmic relationship between RSS value and the sender-receiver distance



Linear relationship between RSS value and the transmission power



RSS saturation is observed when the distance decreases



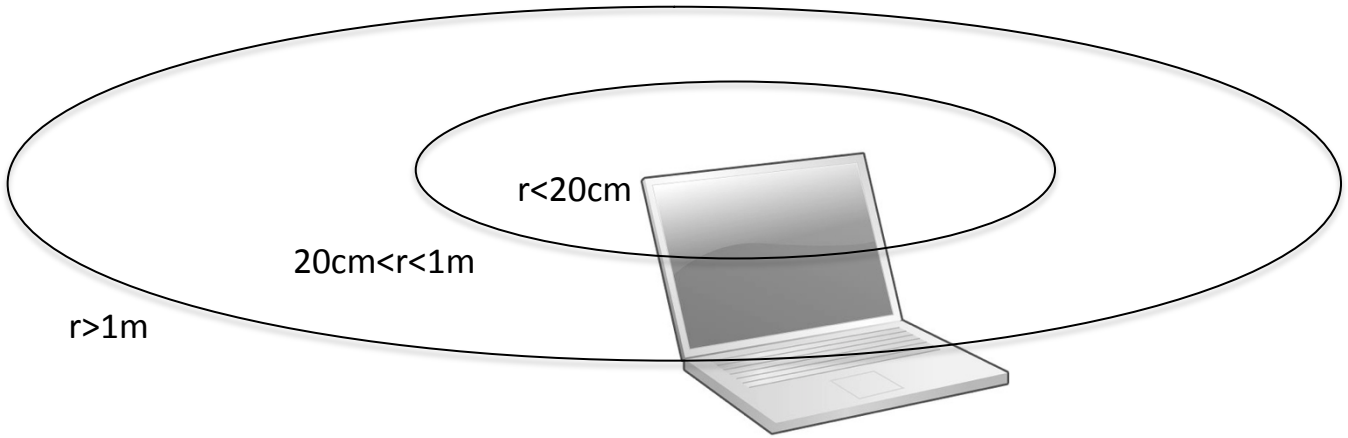
Prototype

Receiver


Sender

- Modify the driver to export RSS values seperately
- Threshold setting:
  - $r_H = -r_L = 11$
  - $\sigma_{valve} = 0.6$
  - $T_{valve} = 1s$

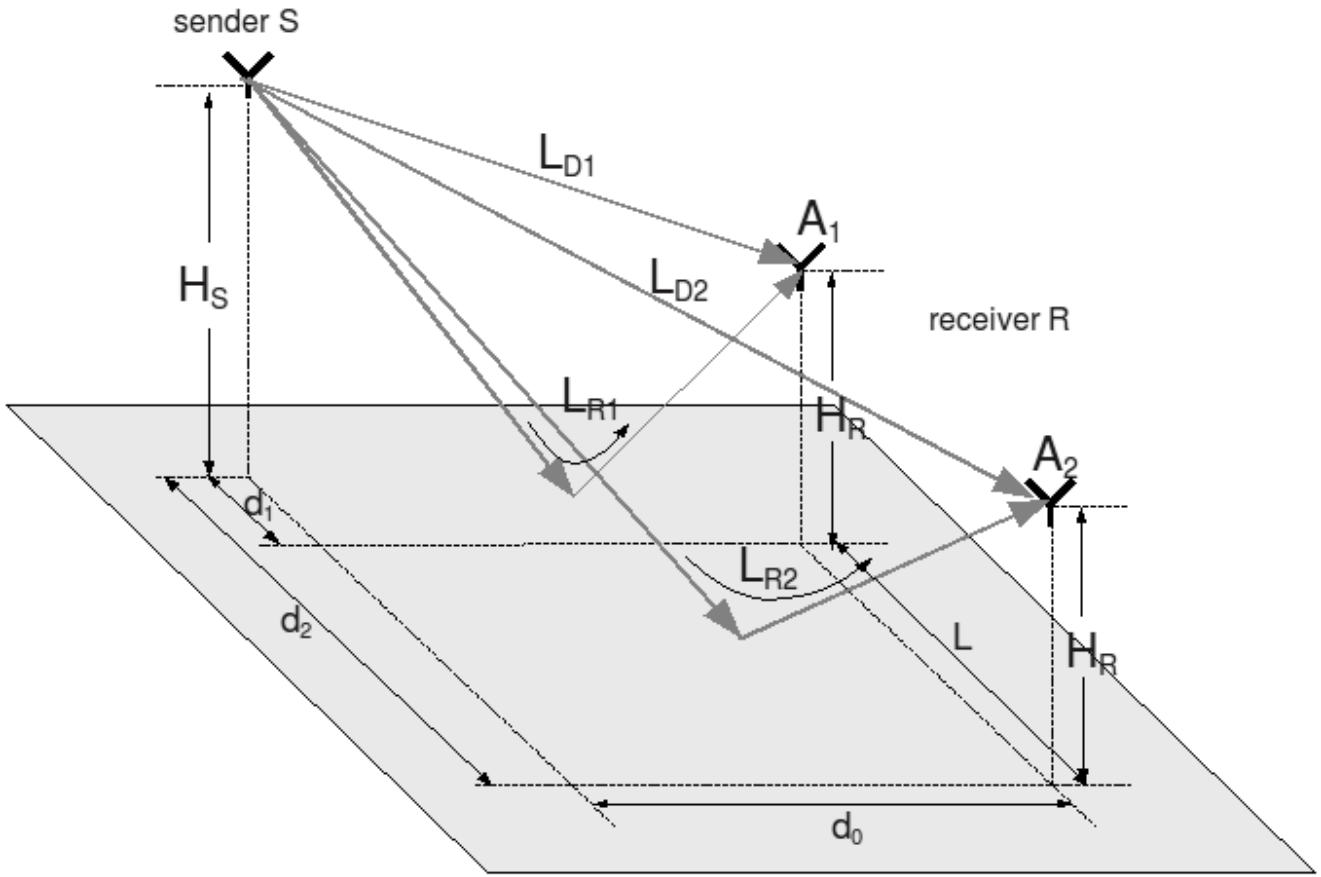
Prototype



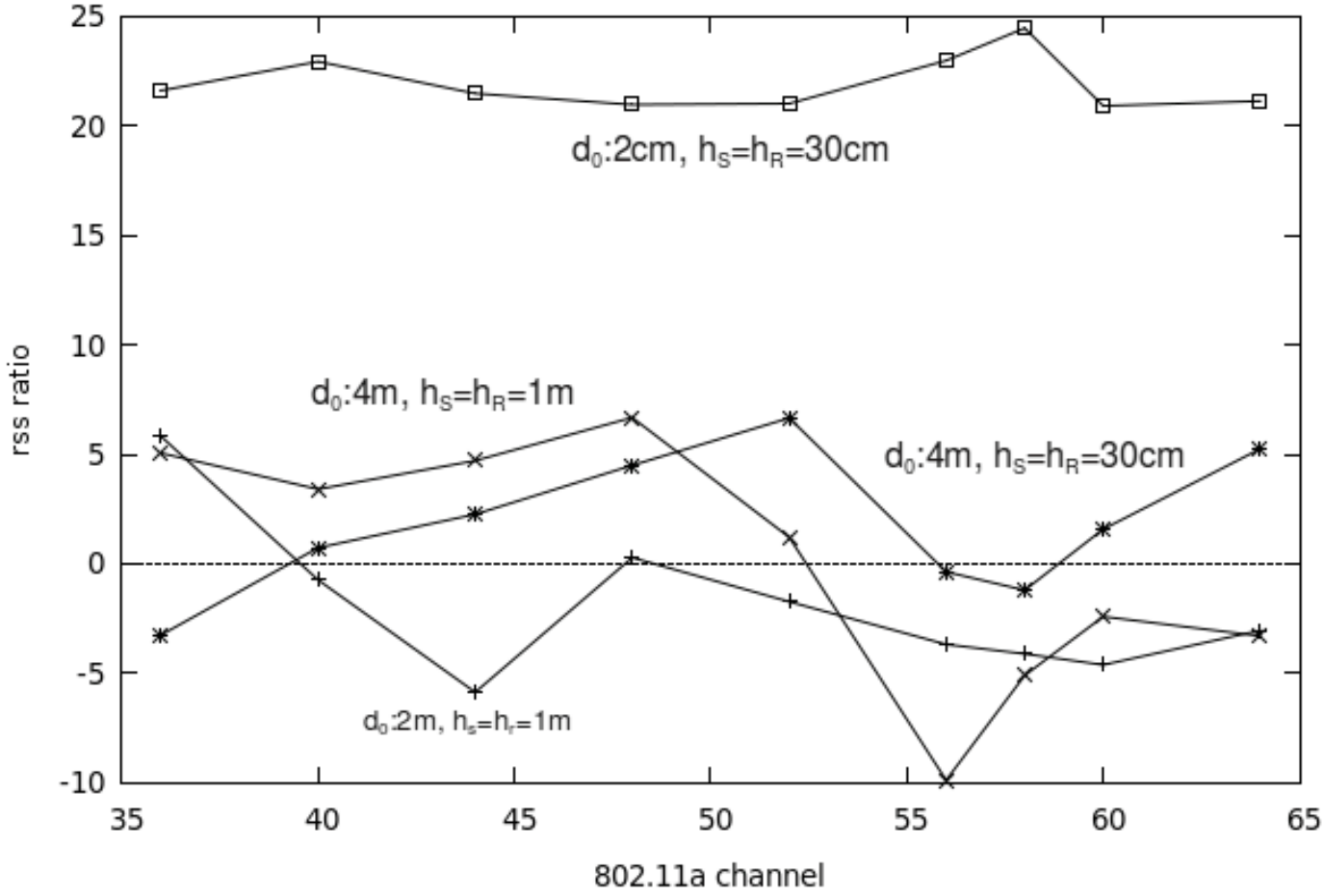
Distance range	$< 20cm$	$[20cm, 100cm]$	$> 100cm$
Success Rage	90%	0%	0%
Failure Rate	10%	100%	100%
Max Mean RSS Ratio	15.62	6.35	3.43

Potential Attack using Multipath Effect

- Attacker may exploit multipath effect to find faraway locations that cause large RSS ratios

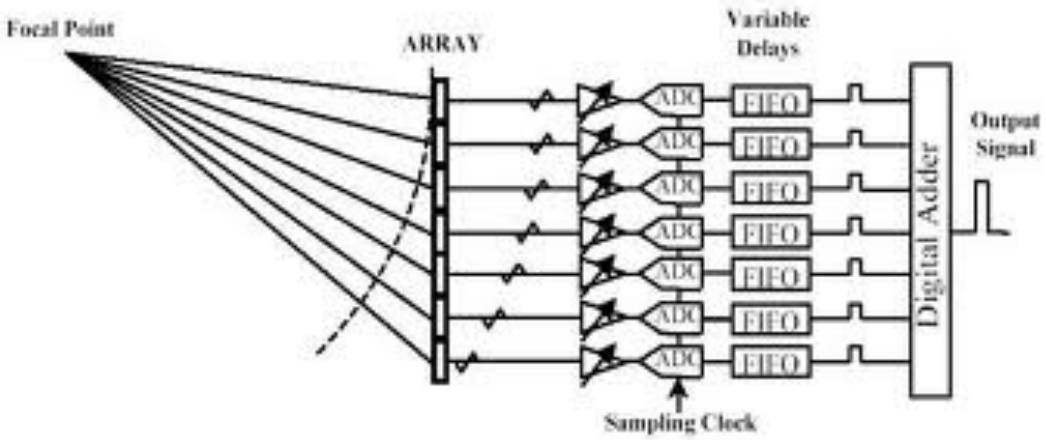


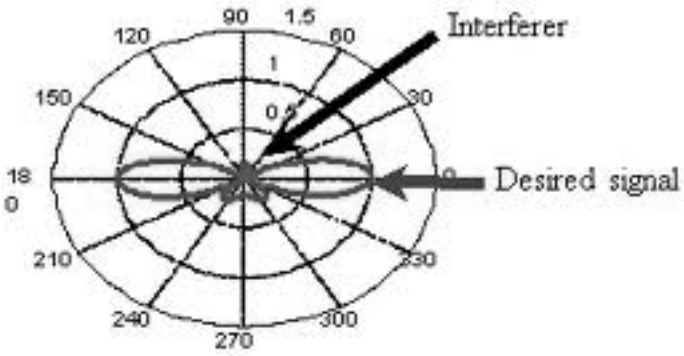
Mitigating with Frequency hopping



Potential Attack using Beam Forming

- Risk: Attackers may form a beam of signal with an antenna array
- Attackers need a very large antenna array (**size of hundreds of meters when L=20cm, d>10m**)





Future works

- Mutual authentication
- Apply our scheme to Bluetooth
- Applications that requires Near Field Communication

Conclusion

- A novel device-pairing scheme
  - Based on proximity
  - Requires no Out-of-Band Channel
  - Requires no user input or verification