RFID READER ANTENNAS

By Chris Cheung
and
Robert Kwong

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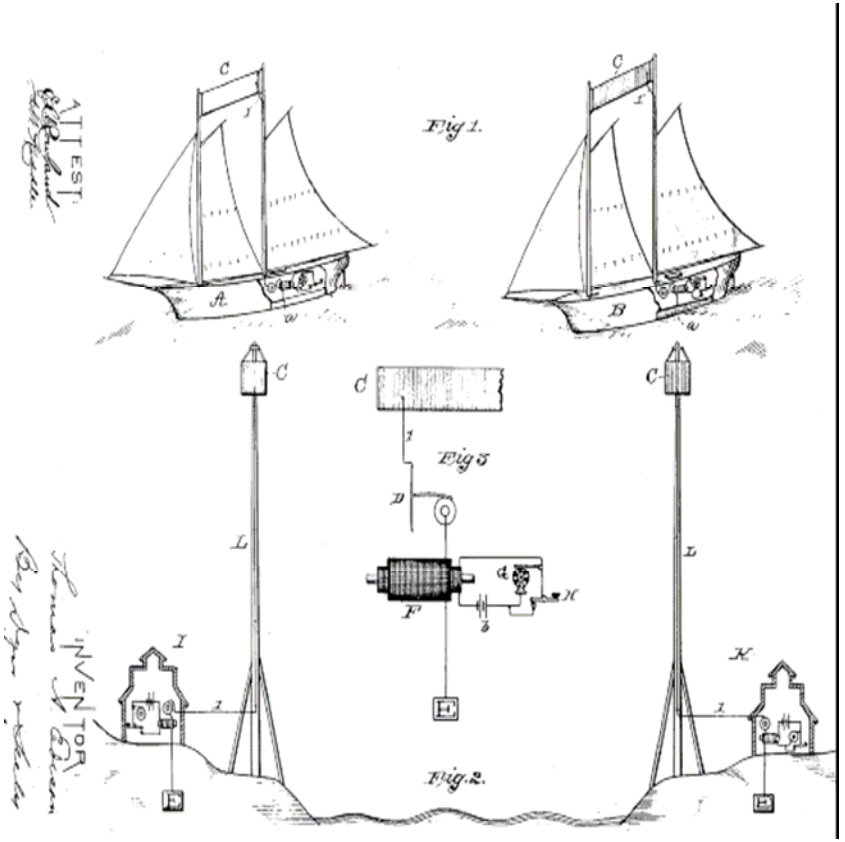
Professor Morelos-Zaragoza

EE296W: RFID Reader Antennas

- Antenna history & terminology
- RFID reader antenna parameters & principles
- Multi-array antenna design examples

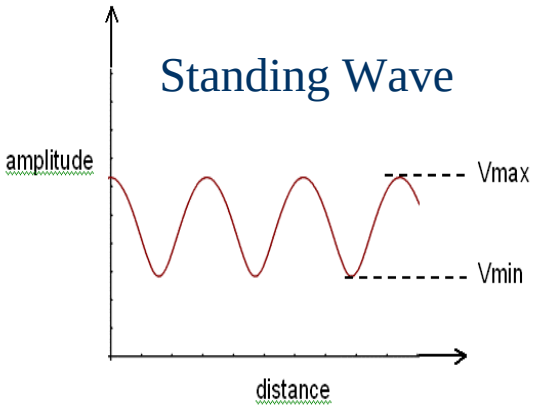
Antenna History

- 1873: Maxwell Equations
- 1885: Edison first to patent antenna system; sold to Marconi.
- 1888: Hertz used antenna to validate Maxwell Equations
- 1901: Marconi first to develop long distance antenna to transmit from England to Newfoundland.



Picture courtesy of US patent 465971.

Antenna Terminology



- Voltage standing wave ratio (VSWR)
- Bandwidth Factor (BWF)
- Antenna pattern
- Elevation & Azimuth
- Antenna Gain (in dBi)
- Directivity & Efficiency

$$VSWR = \frac{V_{max}}{V_{min}} = \frac{1+|\rho|}{1-|\rho|}$$

ρ is the reflection coefficient

$$BWF = \frac{f_H - f_L}{f_o} \; in\,(100\%)$$

f_H and f_L are the high and low frequencies

fo is the resonant frequency

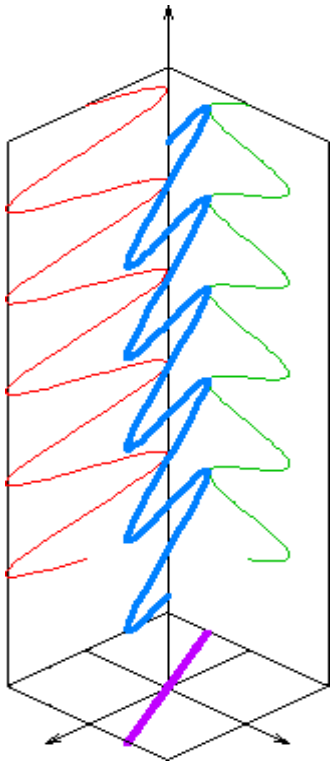
$$D(\theta,\phi) = \frac{P_{max}}{P_{rad \cdot avg}}$$

Pmax is max power in desired direction

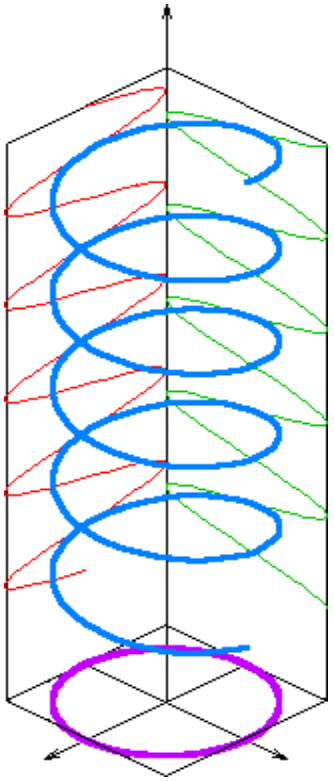
$P_{rad.avg}$ is the average power of antenna

$$Antenna\ Gain\ G = efficiency\ eff\ x\ D\ directivity$$

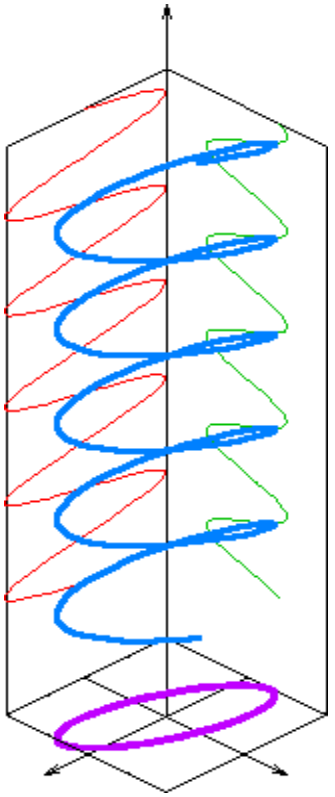
Antenna Polarization Types



Linear



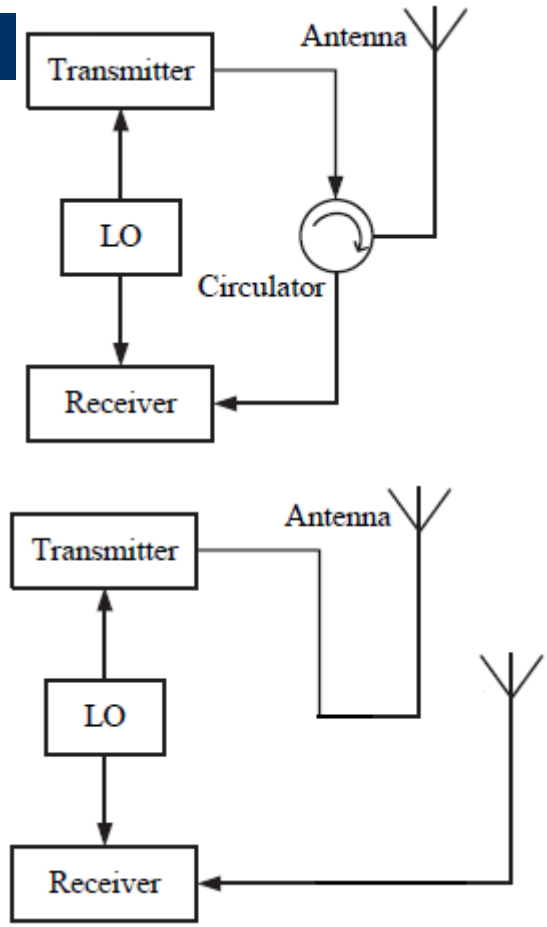
Circular



Elliptical

RFID Antenna Configurations

- Mono-static – Utilizing one antenna for both transmit & receive; requires element such as circulator for full-duplex operation
- Bi-Static – Separate antennas for transmit and receive.



Near Field/Far Field Antennas

- Near Field Antenna – Magnetic coupling dominates within wavelength λ of operating frequency
- Far Field Antenna – Capacitive coupling dominates beyond few wavelengths.

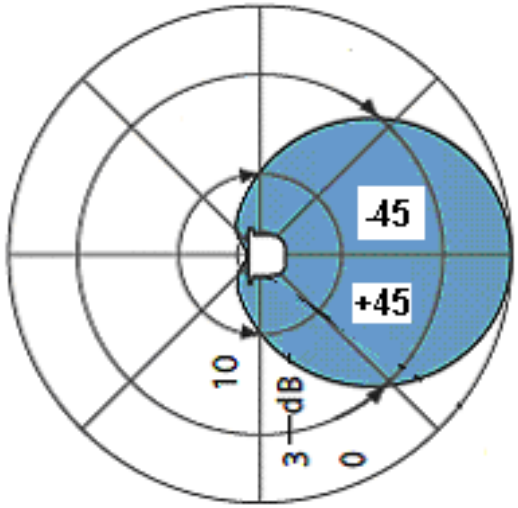
$$R = 0.62\sqrt{\frac{D^3}{\lambda}}$$

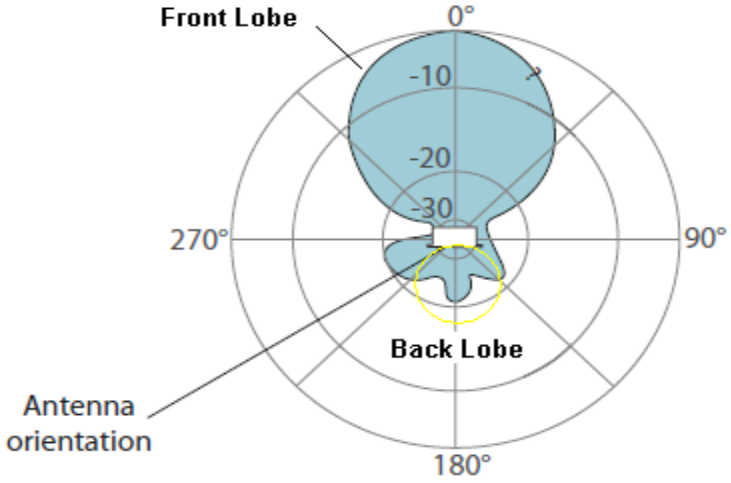
R is farthest edge of Near Field
D is the largest antenna dimension

Type	Pros	Cons
Near Field	Water & Metal resistance	Limited Range
Far Field	Longer Range	Prone to Water & Metal

Reader Antenna Pattern parameters

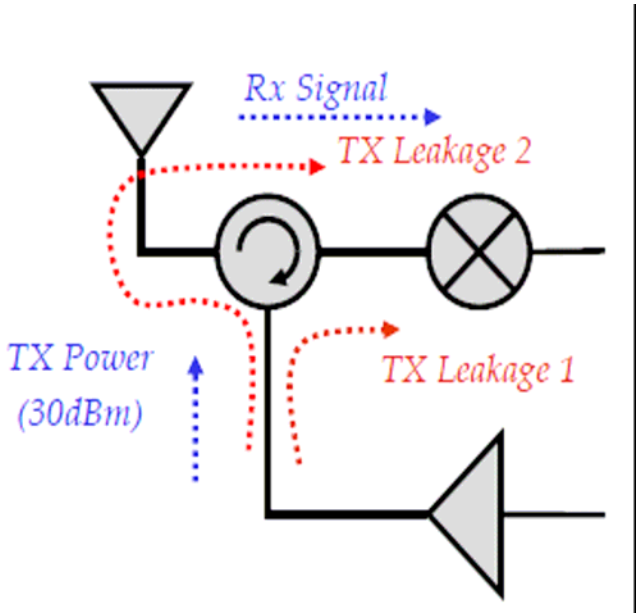
- Antenna Gain – Typically 6 to 12 dBi; higher value narrows pattern more
- 3dB Beamwidth – angular measure of half power. Example: 90°
- Front/Back Ratio – ratio of main frontal lobe to back lobe in dB. Example: F/B Ratio=18dB
- Can also use multi-antenna array for beamforming (constructive & destructive interference to shape antenna pattern)





RFID Reader Sensitivity: Mono-static Case

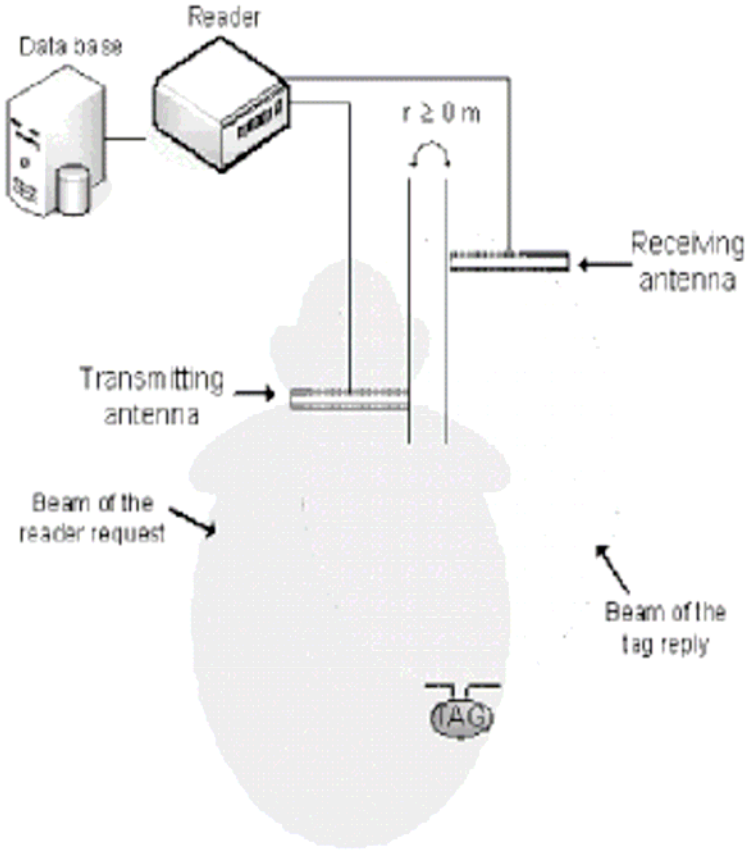
- Affected by 2 different transmit leakages into receive path
- Tx Leakage 1: Leak through circulator; isolation of 20 to 40dB.
- Feed-forward method applied to circulator design can add extra 30dB isolation.
- Tx Leakage 2: Transmit reflection from antenna due to high VSWR or poor matching.



Example: 30dBm transmit with 6dBi Antenna (EIRP 4W NA) with poor matching, circulator of 20dB isolation may have receive sensitivity of only –30dBm or worst.

RFID Reader Sensitivity: Bi-static Case

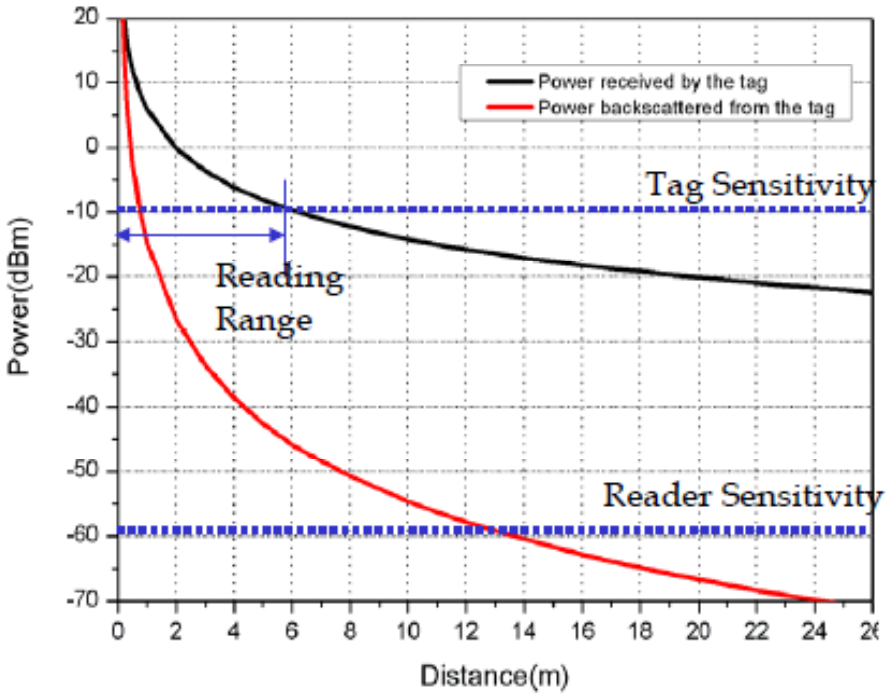
- Internal isolation of RF receive and transmit tracks.
- External separation of antennas to avoid antenna pattern overlap
- Best way is to stagger so transmit antenna further out than receive antenna.



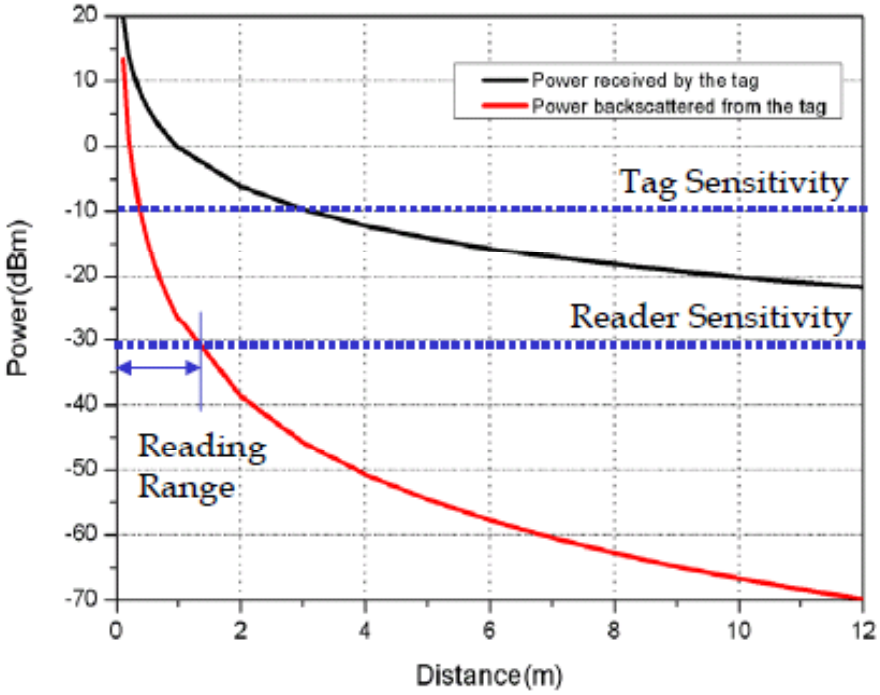
K. Penttilä, L. Sydänheimo, M. Kivikoski, “Implementation of Tx/Rx isolation in an RFID reader,” Int. J. Radio Frequency Identification Technology and Applications, Vol 1, 2006, pg 12

Overall Interrogation Zone

Power Limited Case



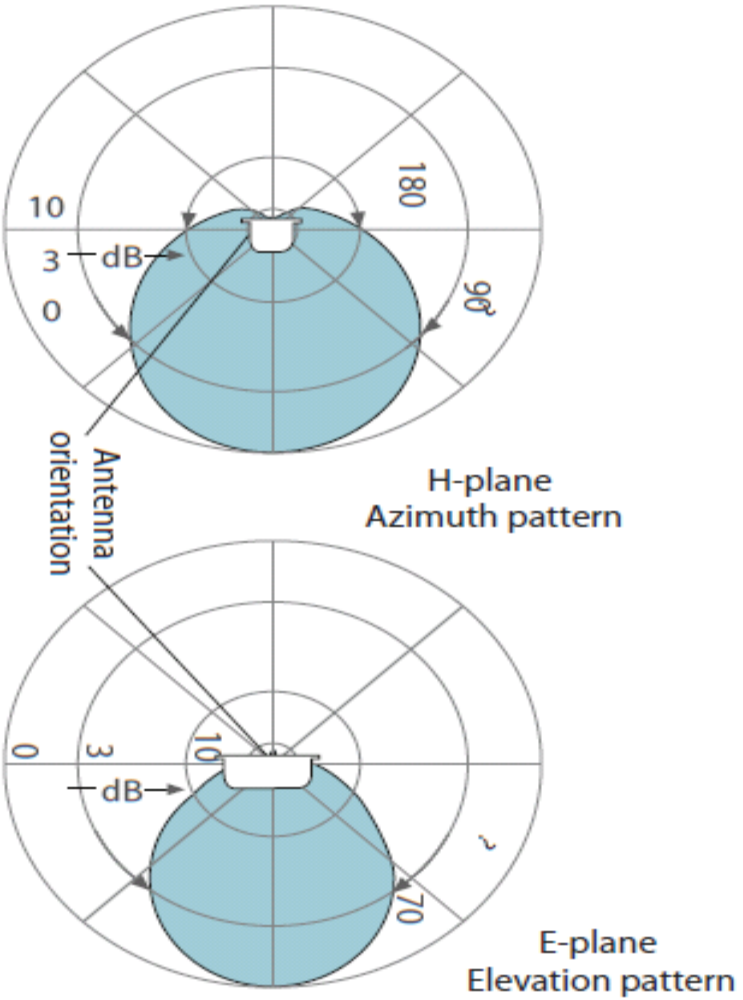
Reader Sensitivity Limited Case



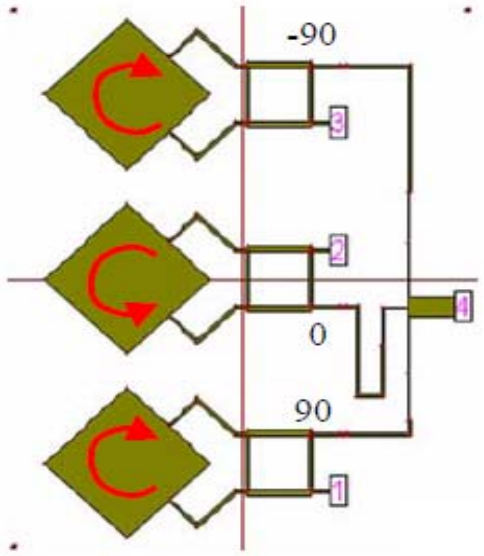
J. Yu,"UHF RFID Reader Front-End", KAIST RF System Solution Lab, August 2007

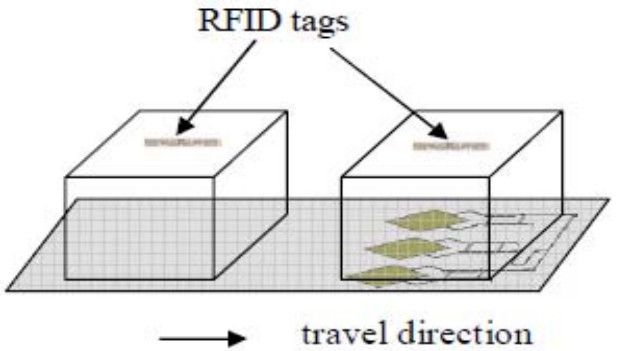
RFID Reader Antenna Datasheet Example: Intermec IA36A

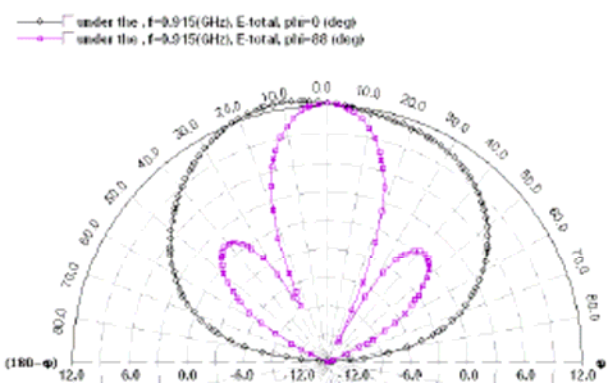
Description
868, 6dBi, Vert Pol, N
Frequency Range
865-928 MHz
Gain
6 dBi
Impedance
50 Ohms
VSWR
<1.5:1
Axial Ratio
N/A
Polarization
Vertical
Front-to-Back Ratio
>20 dB
Maximum Input Power
100 Watts (at 50°C)
H-Plane Beamwidth
90 degrees (half power)
E-Plane Beamwidth
70 degrees (half power)

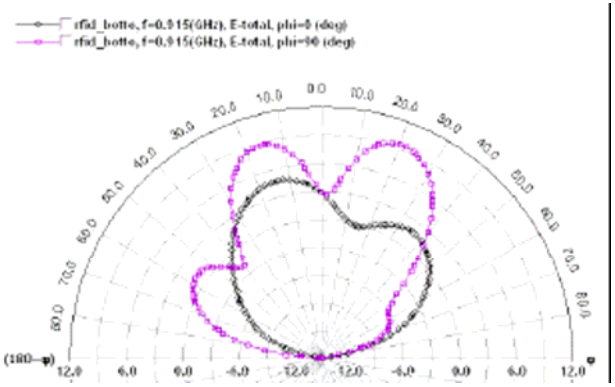


RFID Antenna Design: Multi-Array Antennas beamforming.



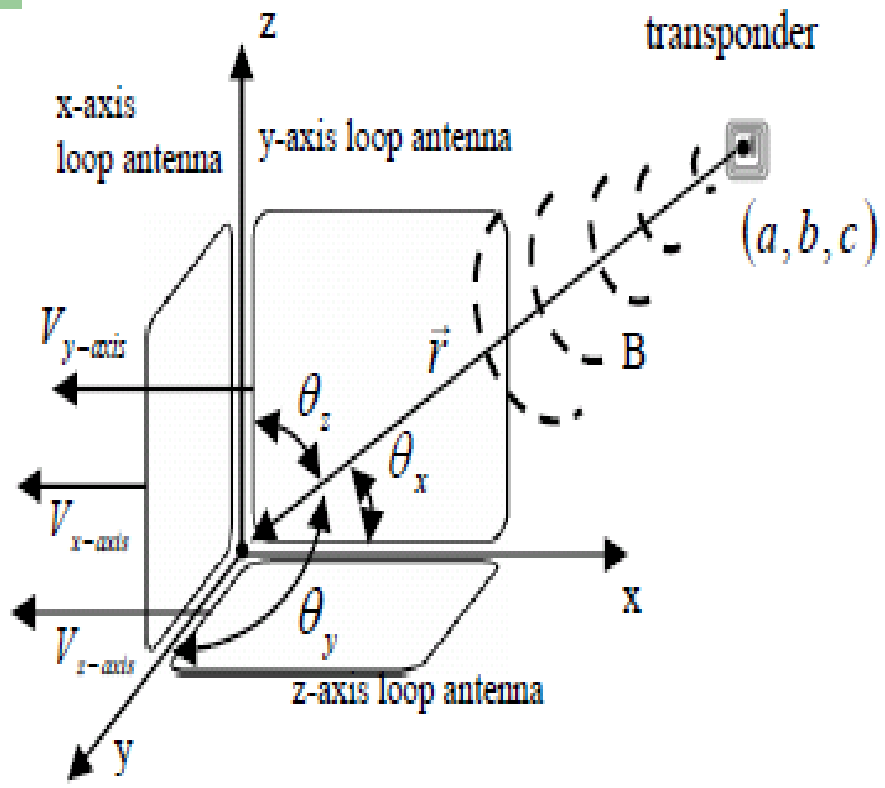


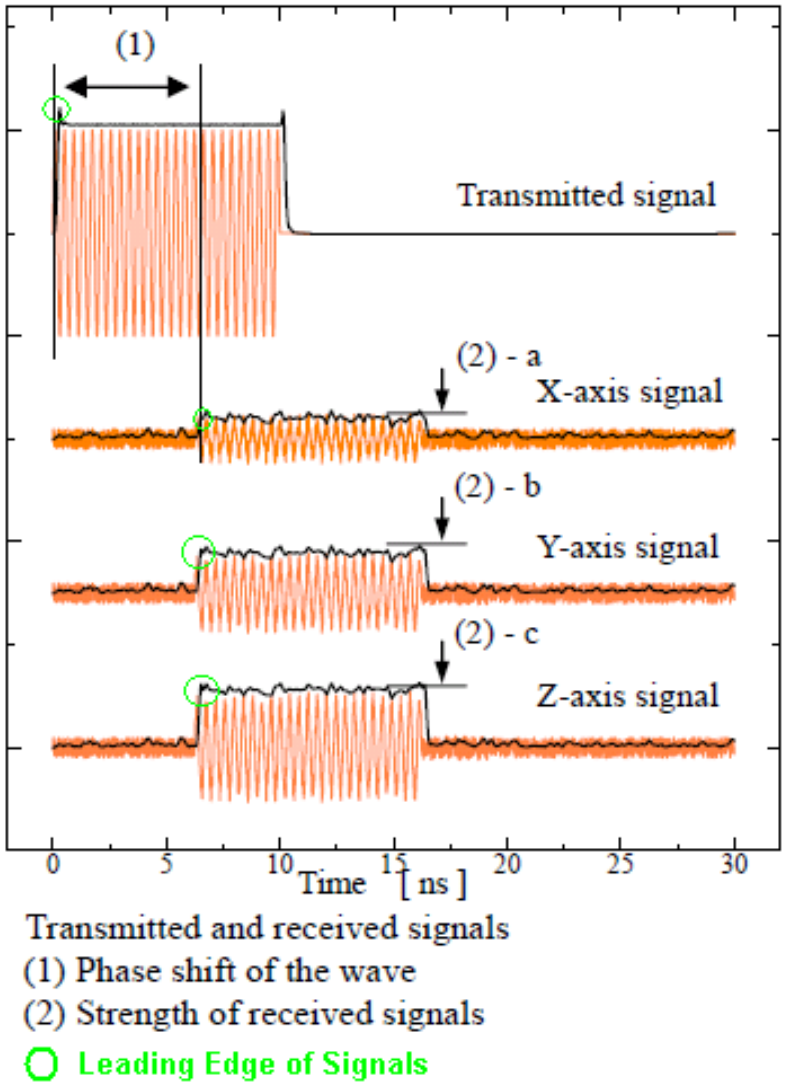




Z. Liu, “A 3 Patch Near Field Antenna for Conveyor Bottom Read in RFID Sortation Application”, IEEE, 2006, pg 1-4.

RFID Antenna Design: 3D Location Detection





Transmitted and received signals
(1) Phase shift of the wave
(2) Strength of received signals
Leading Edge of Signals

M. Kim, T. Takeuchi, N. Chong, "A 3-axis Orthogonal Antenna for Indoor Localization", pg. 2-3.

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Conclusion

- Near Field Antennas attractive for very short interrogation range and resistance against water or metal interference
- Radiated power and proper Tx/Rx isolation for high reader sensitivity are keys for extended RFID reader read range
- Antenna Gain, 3dB Beamwidth, F/B ratio gives insight on antenna radiation pattern shaping
- Multi-Antenna configuration can be used for beamforming or diversity or location detection.