RFID/NFC Technology

With emphasis on physical layer

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List of Abbreviations

- RFID: Radio Frequency Identification.
- NFC: Near Field Communication.
- UWB: Ultra Wide Band.
- ASK: Amplitude Shift Keying.
- FSK: Frequency Shift Keying.
- ECMA: European Computer Manufacturers Association.
- FCC: Federal Communications Commission.
- CEPT: European Conference of Postal and Telecommunications Administrations. (French).
- ERP: Equivalent Radiated Power.
- EIRP: Equivalent Isotropically Radiated Power.

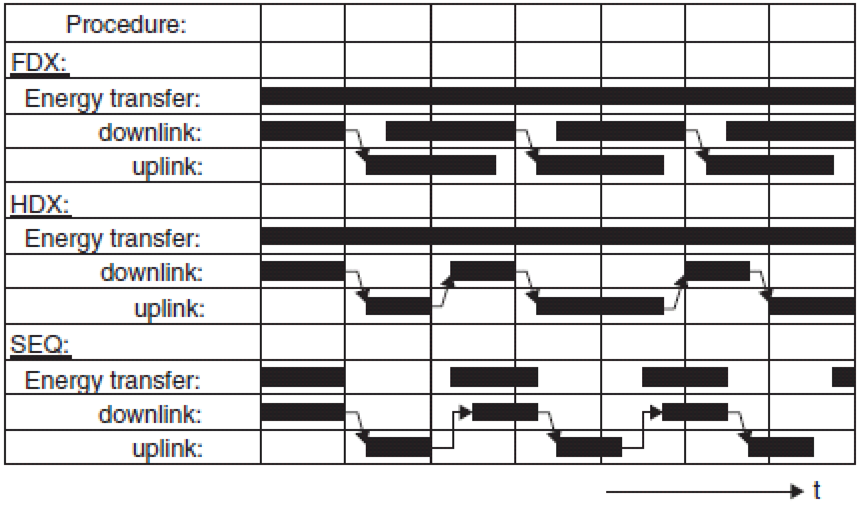
RFID/NFC around us.

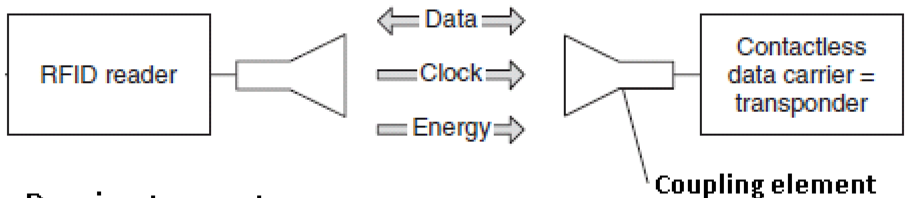
RFID Definition

- Wireless non-contact system.
- Used for automatic identification.
- Made of two separate parts
  - A reader or interrogator.
  - A transponder or tag containing data.
- Works from <1cm range to >10m.
- Frequency: from ~135 Khz to 5.8 Ghz range.
- Two types of tags:
  - Passive: has no energy source except the reader.
  - Active: has a battery or another form of energy source (Energy harvesting).

RFID Definition

- Communication:
  - Full duplex/ Half duplex.
  - Sequential Procedures.
- Data space on the tag: few bytes to several kilobytes.





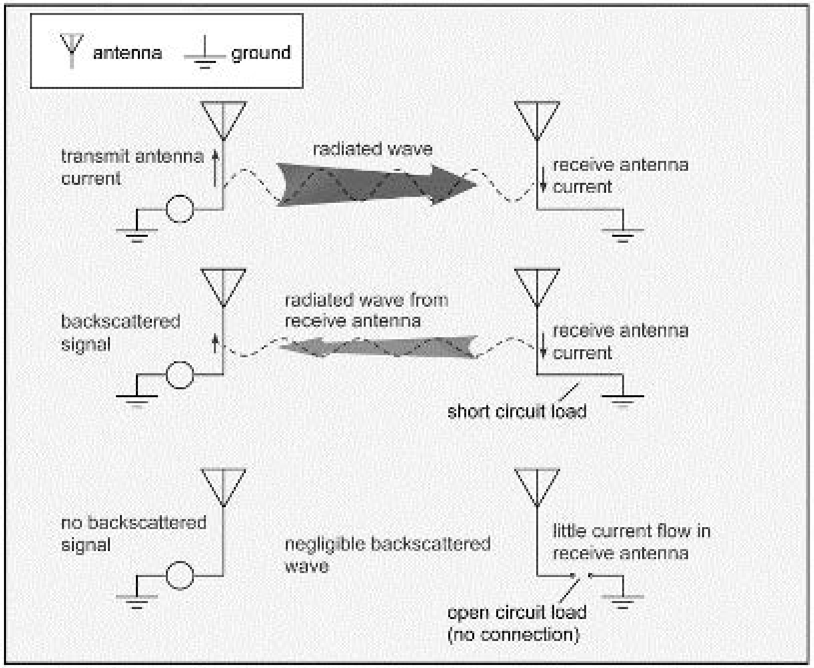
Passive tag system

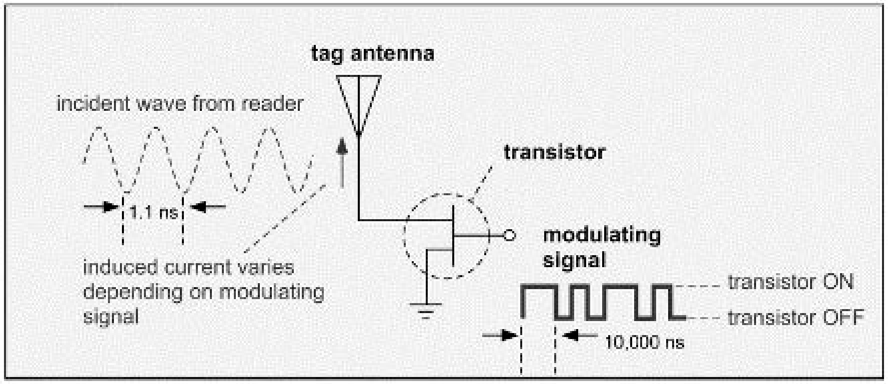
i. Klaus Finkenzeller, RFID Handbook Fundamentals and applications in Contactless Smart cards, radio frequency identification and near field communication, Third edition 2010

ii. Bekir Bilginer, Paul-Luis Ljunggren, Near Field Communication, Master's Thesis, Lund University, February 2011.

RFID COUPLING

- Backscattering:
  - the signal leaves the reader.
  - hits the tag, parts of the signal is reflected back.
  - The reflected signal properties can be changed by adding a load across the tag antenna (modulating).

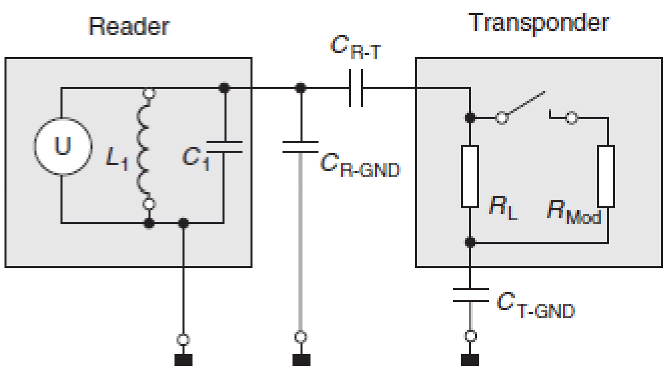




RFID Basics: Backscatter Radio Links and Link Budgets. EETimes. 10/02/2007

RFID COUPLING

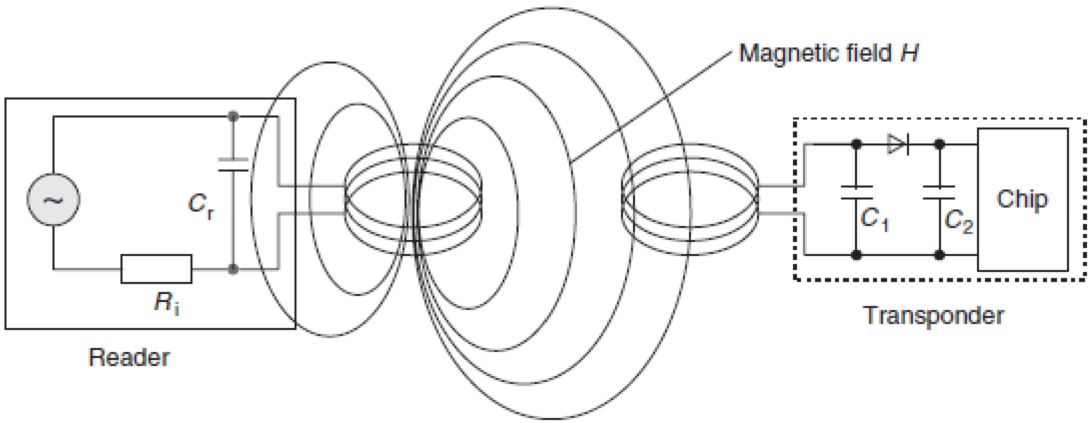
- Capacitive:
  - The tag is in very close proximity (inside the reader).
  - Plate capacitors constructed from coupling surface isolated from one another.
  - Data transmission is done via load modulation.



Klaus Finkenzeller, RFID Handbook Fundamentals and applications in Contactless Smart cards, radio frequency identification and near field communication, Third edition 2010

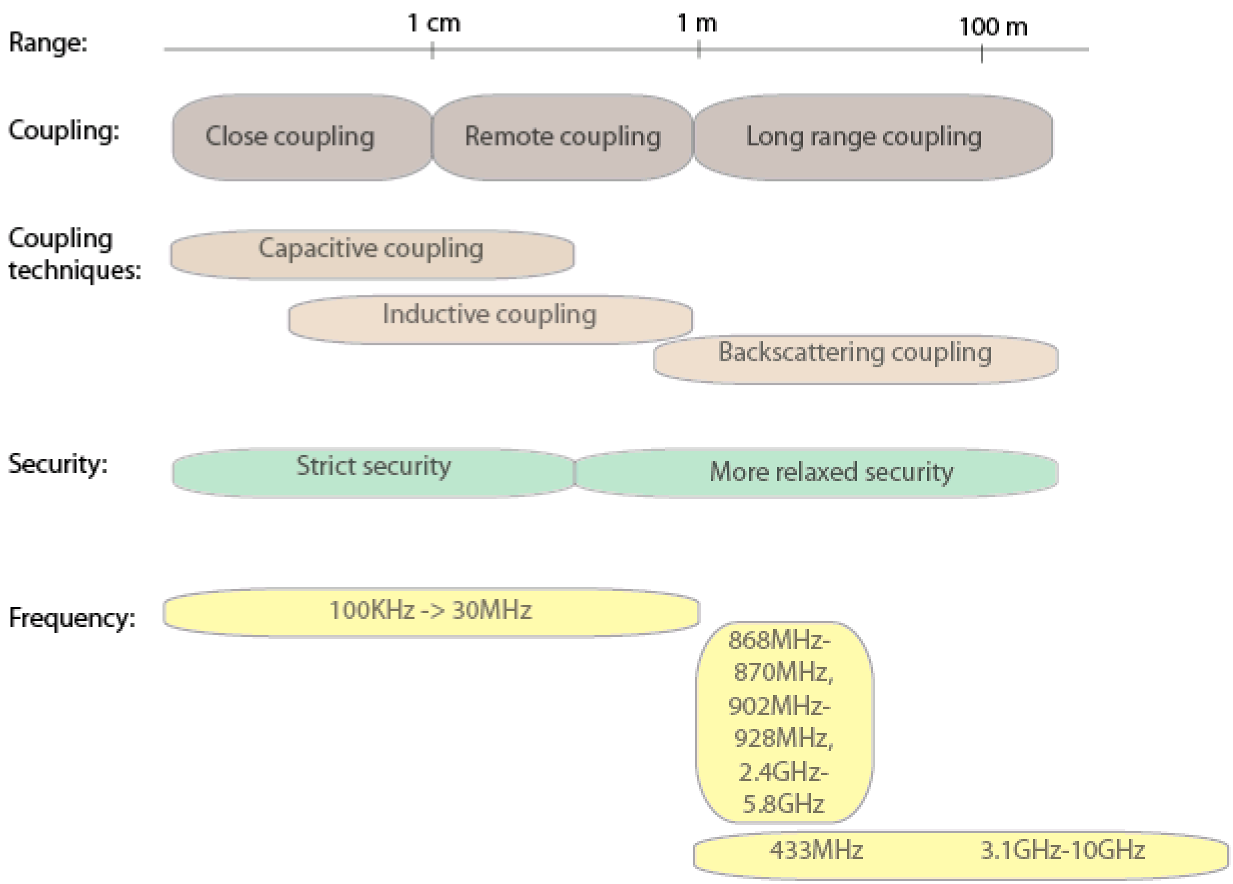
RFID COUPLING

- Inductive:
  - The tag is in close proximity (less than $\lambda/2\pi$) .
  - Mutual inductance between two coils.
  - Data transmission is done via load modulation.



Klaus Finkenzeller, RFID Handbook Fundamentals and applications in Contactless Smart cards, radio frequency identification and near field communication, Third edition 2010

RFID Classification



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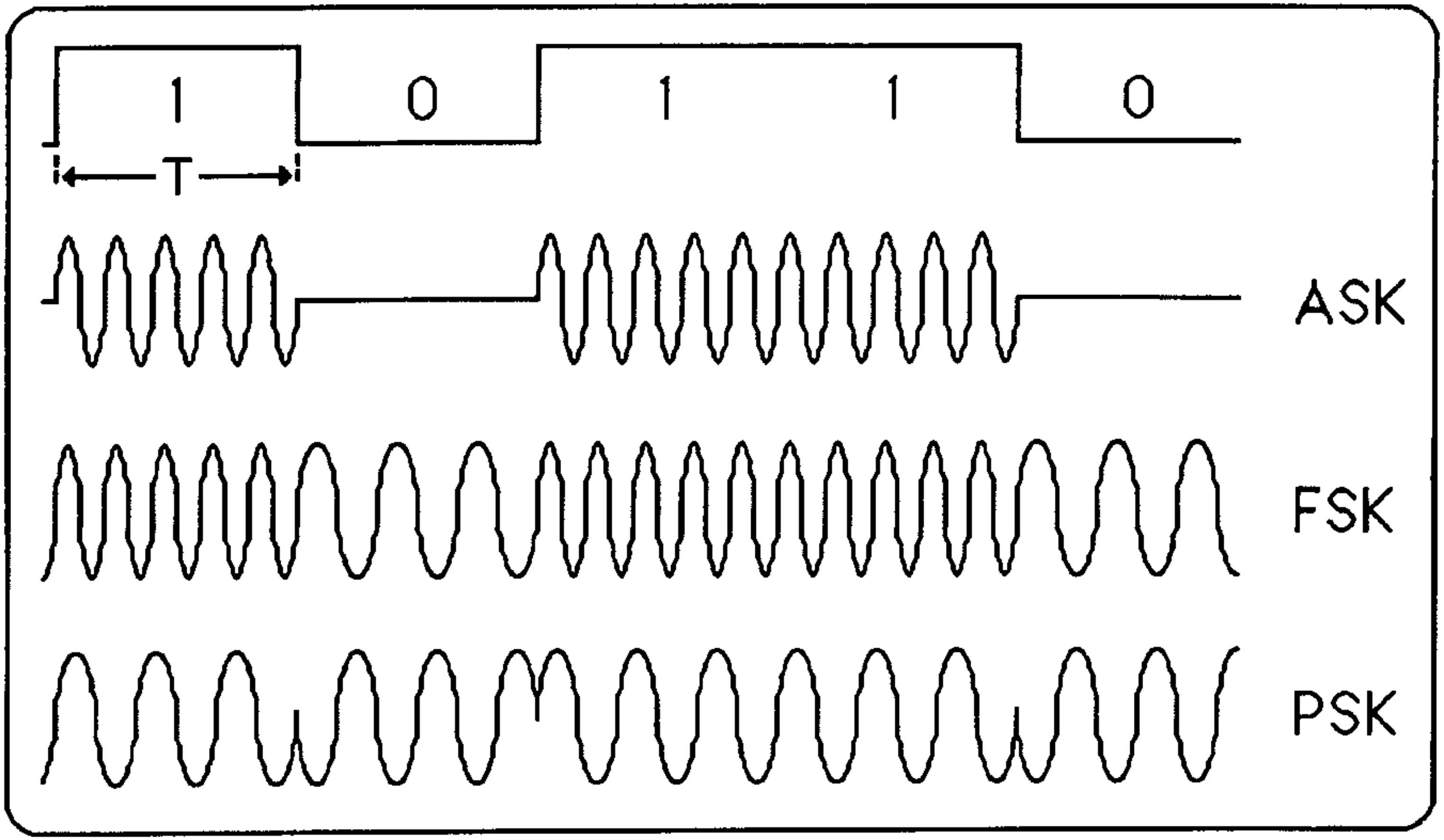
NFC

- RFID with the following properties:
  - Frequency: 13.56MHz ± 7KHz.
  - Range: < 20 cms.
  - Inductive coupling.
  - Data rate: 106 kbps to 424kbps.
  - Tags can be active/passive.
  - Digital Modulation: ASK, PSK or FSK.
  - Standards: RFID standard ISO 14443, ISO 18092 and ECMA-340.

Klaus Finkenzeller, RFID Handbook Fundamentals and applications in Contactless Smart cards, radio frequency identification and near field communication, Third edition 2010

Modulation: ASK, FSK, PSK

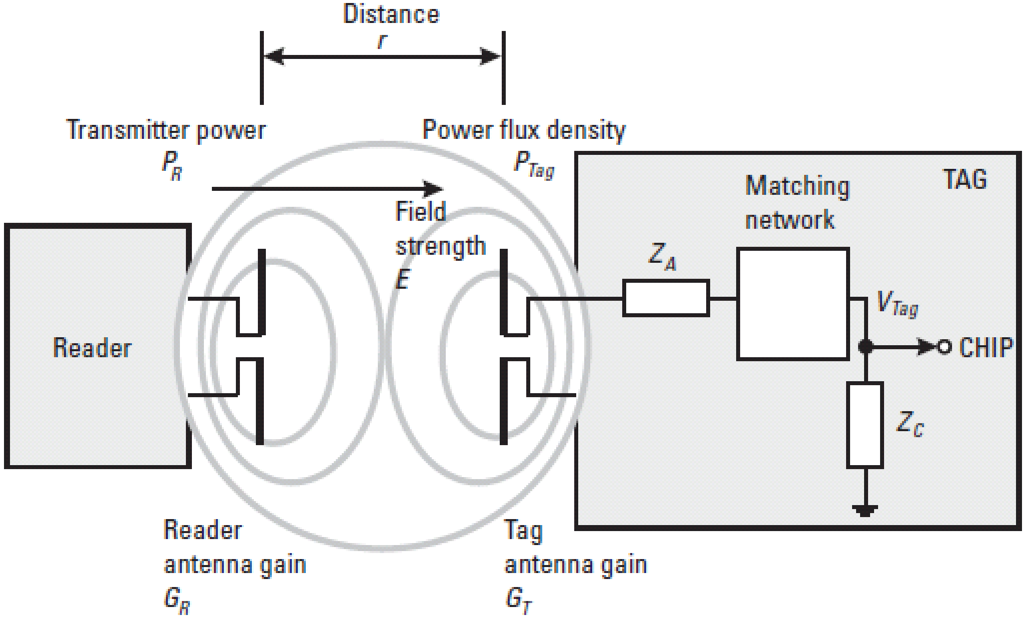


http://www.sit.fi/~grahn/fortmod/MT-6.html

RFID PHYSICAL MODEL

1. Forward Power Transfer:
   - Sufficient power must be transmitted to energize the circuit inside the transponder.
2. The Radar Equation:
   - The reader must be able to detect and resolve the scattered signal returned.

RFID: Forward Power Transfer



$$E^2/120\pi = P_R G_R / 4\pi r^2$$

$$P_{Tag} = (E^2/120\pi)(\lambda^2/4\pi)G_T = V_{tag}^2 / R_c$$

$$P_{Tag} = (P_R G_R / 4\pi r^2)(\lambda^2 G_T / 4\pi) = P_R G_R G_T \lambda^2 / (4\pi)^2 r^2$$

$$V_{Tag} = (\lambda / 4\pi r)\sqrt{P_R G_R G_T R_c}$$

Power transmitted is regulated by FCC (in EIRP) and CEPT(in ERP).

i. Refer to the Antenna presentation (pages 10-12) by Håvard Austad
ii. Harvey Lehpamer, RFID design principles, Chap 5. Artech House Publishers, December 2007

RFID: Forward Power Transfer Example

Freq = 915 MHz.
V= 1.6 Vrms.

Gains = 2dBi (~1.6)

Distance = 1m.

$$P_{Tag} = V_{Tag}^2 / R_c = 1.6^2/600 = 0.0043\,[\mathrm{W}]$$

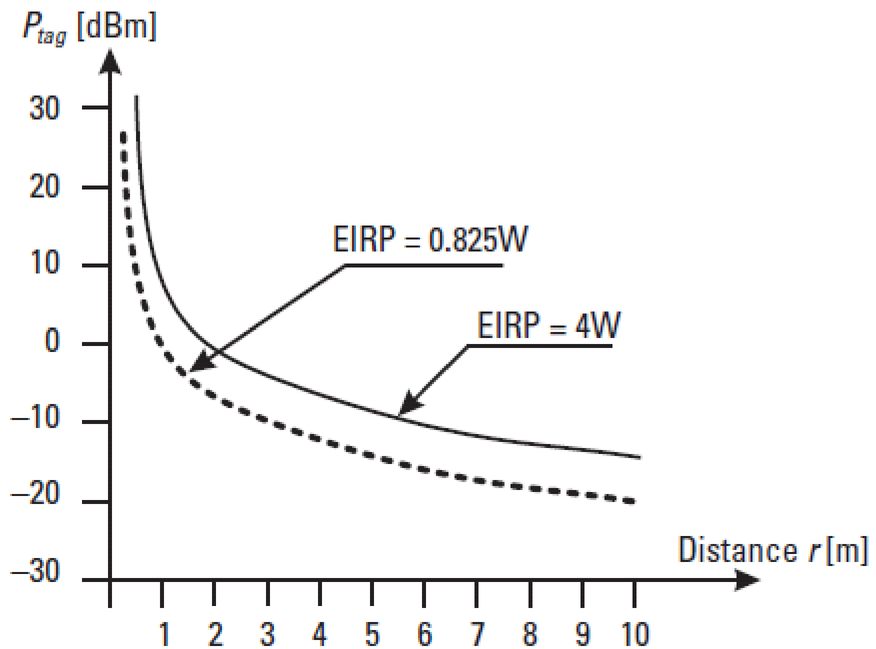
$$P_R = \left(4\pi r V_{Tag}/\lambda\right)^2 \left(1/(G_R G_T G_c)\right)$$

$$P_R = (4\pi \cdot 1 \cdot 1.6/0.33)^2 (1/(1.6 \cdot 1.6 \cdot 600))$$

$$P_R = 2.416\,[\mathrm{W}]$$

$$G[\mathrm{dBi}] = 10 \log G \rightarrow G = 10^{\frac{G[\mathrm{dBi}]}{10}}$$

EIRP = P_R. G_R ~ 4W



ERP	EIRP	dBm	Gain	Power amplifier in dB
500mW	825mW	29dBm	2dBi	27dBm
2W	3.3W	35dBm	2dBi	33dBm
2.4W	4W	36dBm	2dBi	34dBm

Harvey Lehpamer, RFID design principles, Chap 5. Artech House Publishers, December 2007

RFID: Radar Equation

- The larger the reflective area, the greater the reflective energy (Radar cross section, RSC).
- In RFID, Differential RSC or ΔRSC (Due to modulation).
- Effective aperture: $A_e = \lambda^2 G_T / 4\pi \; [m^2]$
- Differential reflection coefficient: Δρ around 0.5 but less than 1.
- $\sigma = \Delta_{RCS} = A_e \cdot G_T \cdot (\Delta\rho)^2 = \frac{\lambda^2 G_T^2 (\Delta\rho)^2}{4\pi} \; [m^2]$
- Power Flux density: $S = \frac{P_R}{4\pi r^2} \; [W/m^2]$,
- Directional power flux density: $S_D = S \cdot G_R$
- Power returned to the reader: $P_{Ret} = \frac{P_R}{4\pi r^2} \cdot G_R \cdot \sigma \; [W]$
- Power density at the reader: $S_{REC} = \frac{P_{Ret}}{4\pi r^2} = \frac{P_R \cdot G_R}{(4\pi)^2 r^4} \cdot \sigma$

f [MHz]	λ [m]	r [m]	P Reader [W]	P Reader [dBm]	Reader Antenna Gain	Tag Antenna Gain	$\Delta\rho$	σ [m^2]	P Received [μW]	P Received [dBm]	Power Ratio [dB]
915.00	0.33	1.00	2.00	33.01	1.60	1.60	0.50	0.0055	1.5185	–28.19	–61.20

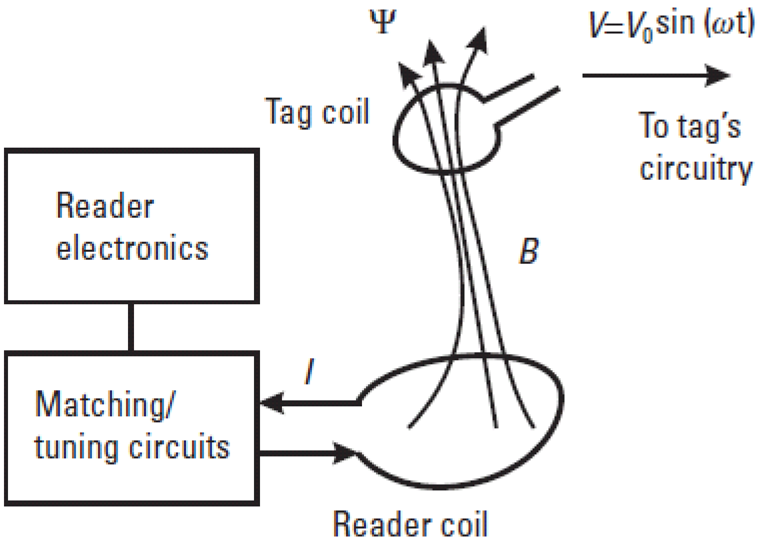
Harvey Lehpamer, RFID design principles, Chap 5. Artech House Publishers, December 2007

NFC: Inductive Coupling

- Magnetic flux density: $B = \frac{\mu_0 I N a^2}{2r^3} \left[\text{Weber/m}^2 \text{ or tesla}\right]$
  - I : Current through the coil.
  - N: Number of windings in reader coil.
  - a: radius of the coil.
  - µ0: permeability of free space ($4\pi x 10^{-7}$ H/m).
  - r: perpendicular distance from coil center. r>>a.
- Resonance Frequency of the reader:

  $$f_0 = 1/2\pi\sqrt{LC}$$

- L: the magnetic flux divided by current. It is affected by: radius of the coil, number of windings, thickness of windings, length of the coil.
- Voltage induced in the tag: $V = -N\frac{d\Psi}{dt}$ $\Psi = \int B \bullet dS$ $V_{Tag} = 2\pi f N Q B (S \cos\alpha)$
  - S: Surface area of the tag coil.
  - Q: Quality factor of resonant circuit.
  - N: Number of windings in tag coil.



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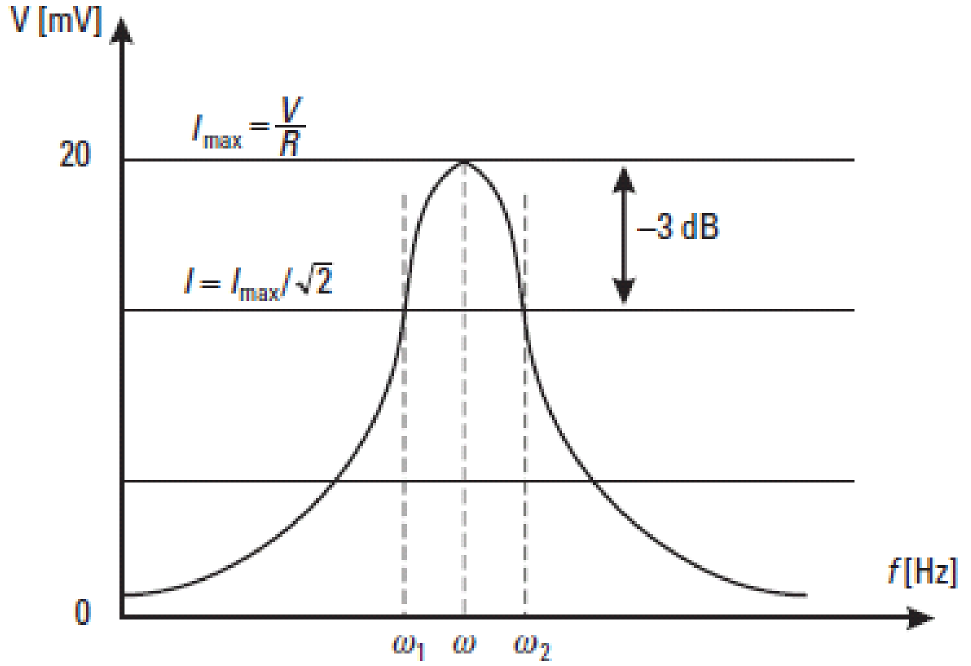
NFC: Inductive Coupling



$$Q = \frac{\omega L}{R_S} = \frac{1}{\omega CR} = \frac{\omega}{\omega_2 - \omega_1}$$

Q is within the range of 20 to 80.

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REFERENCES

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6. Bekir Bilginer, Paul-Luis Ljunggren, Near Field Communication, Master's Thesis, Lund University, February 2011.

My Work

- Nano electronics group at IFI, UiO.
- How smart can and should a Smart Sensor Node be?
- Application: Implanted under the skin glucose sensor (GlucoSence).
- Way forward:
  - A non-volatile memory on the sensor. (Flash)
  - A communication link. (NFC)
  - A communication protocol. (???).
- Interested? Contact me!