RFID and Rectenna Technology

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1. How does RFID work ?

2. How to determine Antenna
   Impedance at RFID Tag ?

3. Rectenna (Rectifier + Antenna)

Hideyuki Nebiya
AMPLET Communication Lab.

Dr. Nebiya's RFID Books

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1. How does RFID work ?

RFID using Radar Technology

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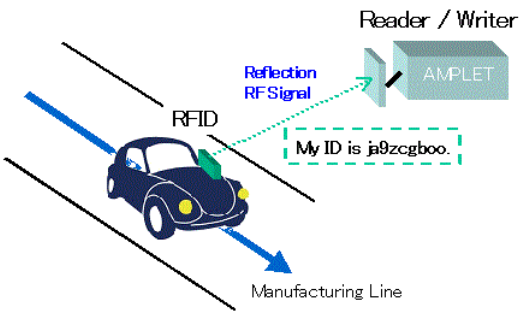
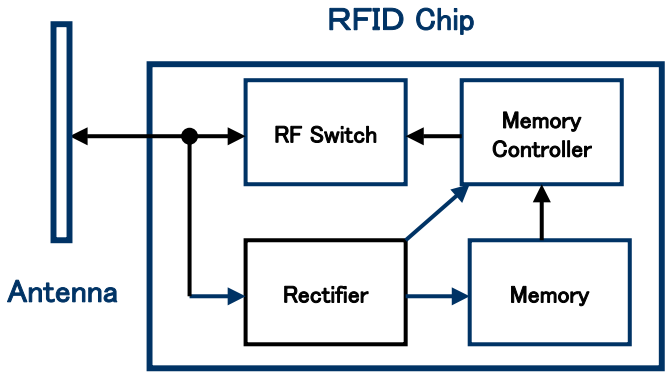


Reader

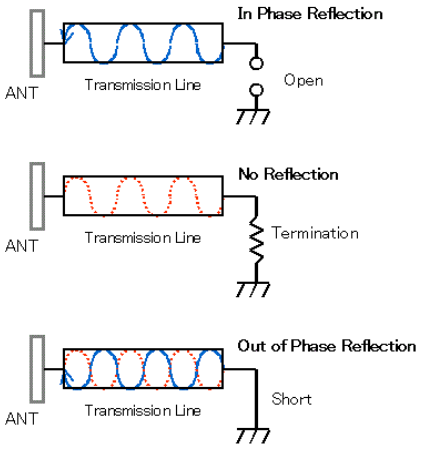
RFID Tag

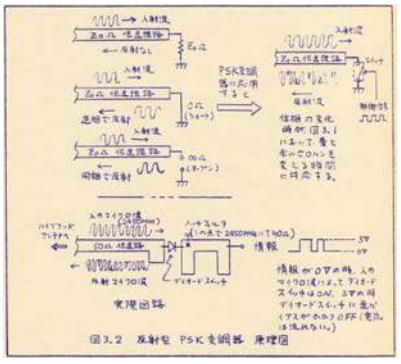
When I moved to Hitachi from Nissan, I considered efficiency of Manufacturing Lines using Radar Technology. Then I invented RFID in 1984.

Typical Block Diagram of RFID Tag

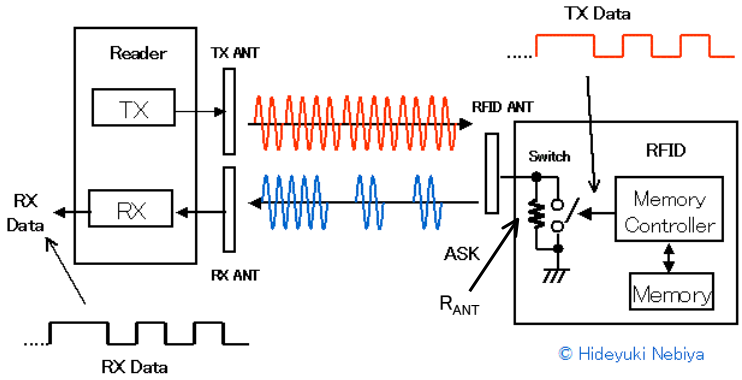


Reflection on Transmission Line

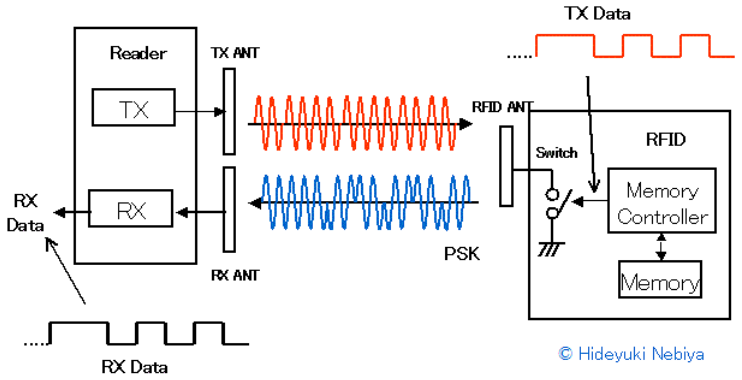




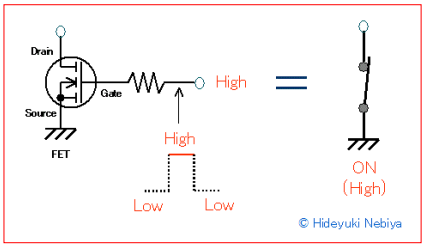
Passive ASK RFID

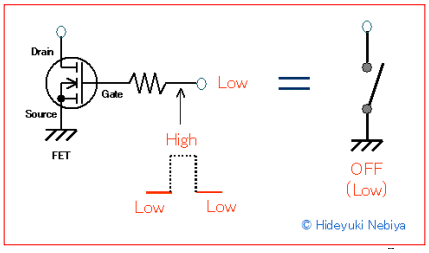


Passive PSK RFID



RF Switch



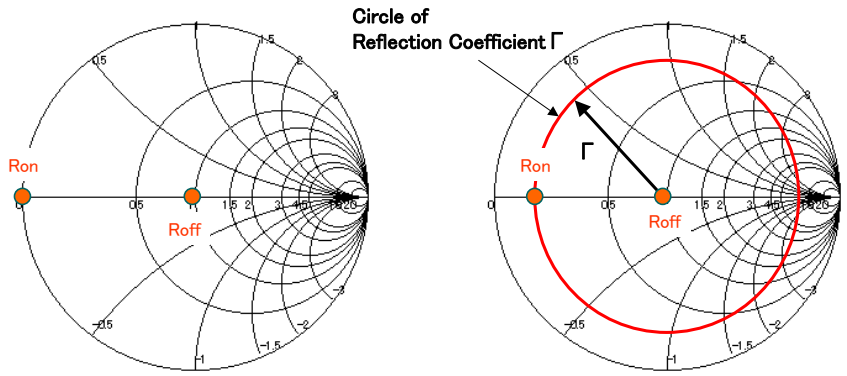


Switch ON **Switch OFF**

2. How to determine Antenna Impedance at RFID Tag ?

In Case of ASK-RFID Tag

In Case of ASK-RFID Tag
Smithcart normalized for R_{ANT}

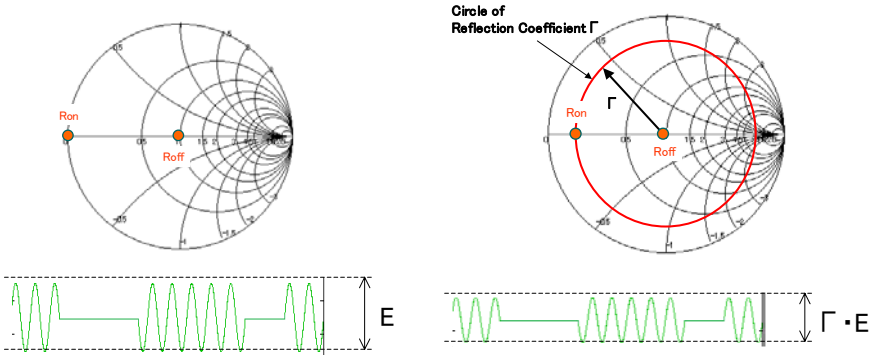


Ideal ASK-RFID
Ron = 0Ω
Roff = R_{ANT}

In Case of ASK-RFID Tag
→ R_{ANT} = Roff

Actual ASK-RFID
Ron =Several Ω
Roff = R_{ANT}

In Case of ASK-RFID Tag
Smithcart normalized for R_{ANT}



Ideal ASK-RFID
Ron = 0Ω
Roff = R_{ANT}

In Case of ASK-RFID Tag
→ R_{ANT} = Roff

Actual ASK-RFID
Ron =Several Ω
Roff = R_{ANT}

In Case of PSK-RFID Tag

In Case of PSK-RFID Tag
Smithcart normalized for R_{ANT}

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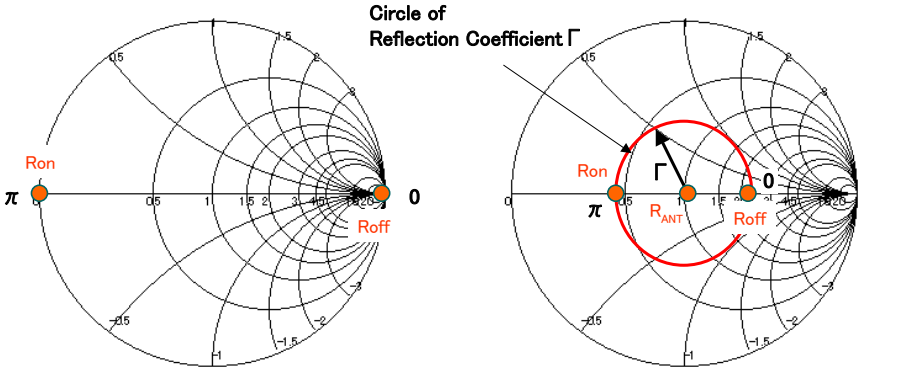

Real PSK-RFID
Ron = 0Ω
Roff = ∞Ω

In Case of PSK-RFID Tag
→ $R_{ANT} = \sqrt{\text{Ron X Roff}}$

Actual PSK-RFID
Ron =Several Ω
Roff = Several Hundreds Ω

In Case of PSK-RFID Tag
Smithcart normalized for R_{ANT}

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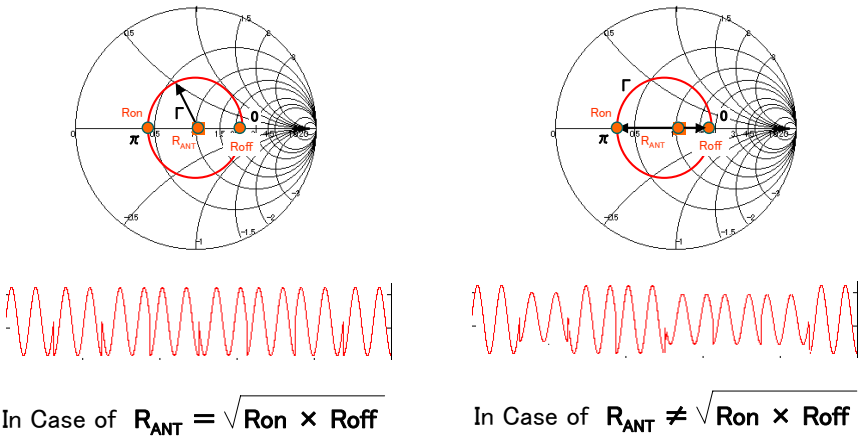
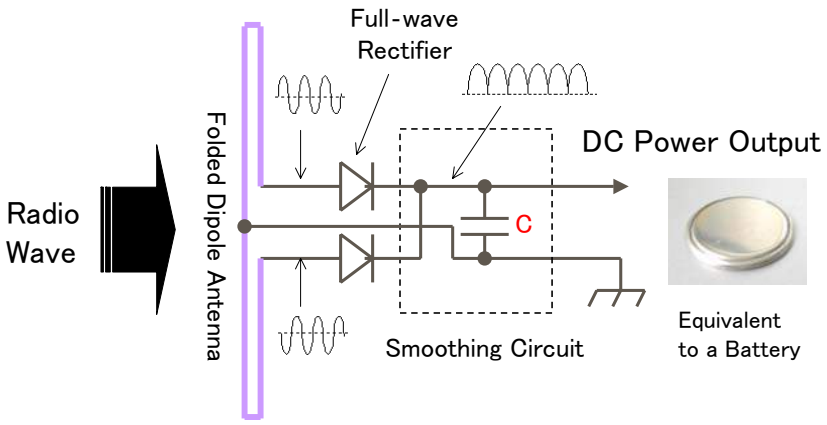


In Case of $R_{ANT} = \sqrt{\text{Ron} \times \text{Roff}}$

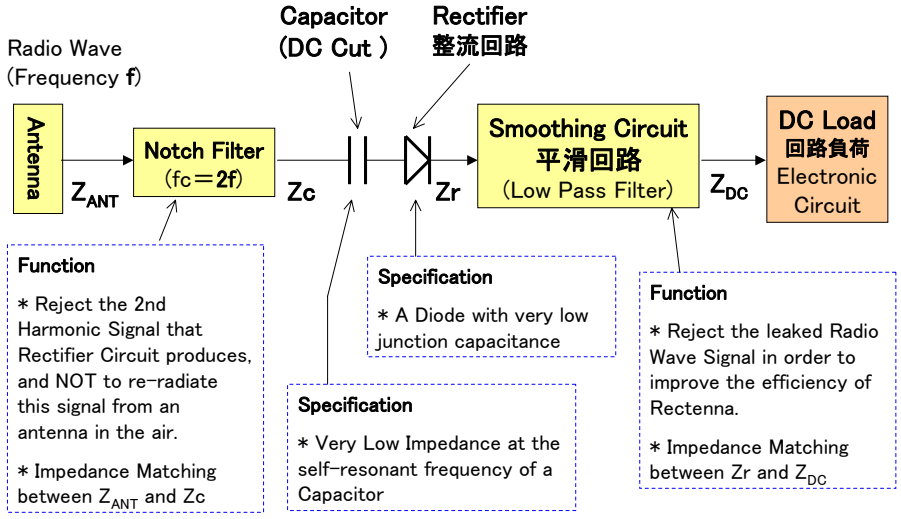
In Case of $R_{ANT} \neq \sqrt{\text{Ron} \times \text{Roff}}$

3. Rectenna (Rectifier + Antenna)

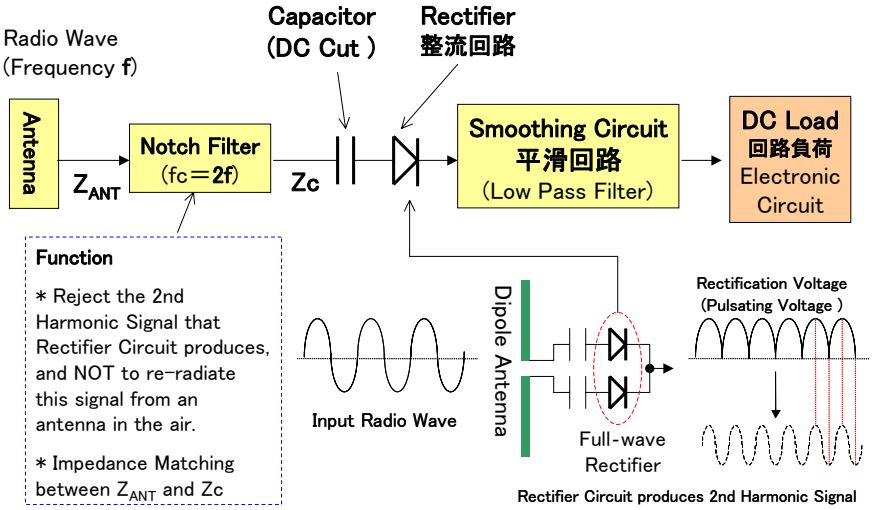
About Rectenna



Block Diagram of Rectenna



Design Know-How → Notch Filter



Design Know-How → Notch Filter

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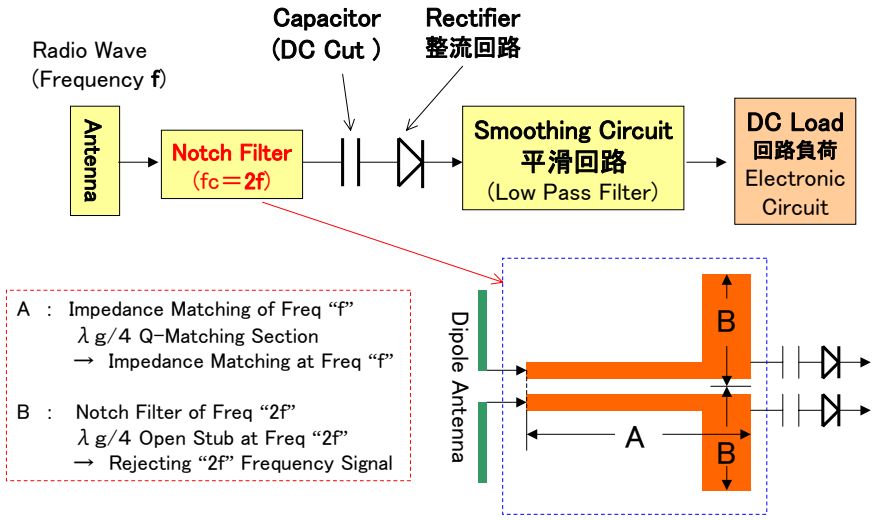

Impedance Matching (Quarter-Wavelength Matching)

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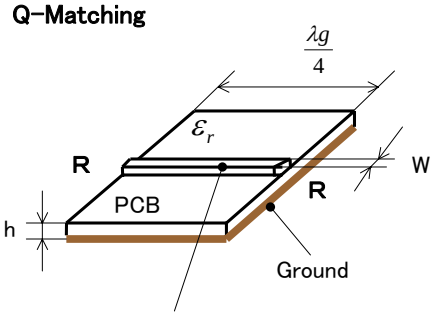
Q-Matching



λ g/4 Transmission Line
Characteristic Impedance ＝ R

$$R_T = \frac{120\pi}{\left(\frac{W}{h}+1\right)\sqrt{\varepsilon_r+\sqrt{\varepsilon_r}}} \quad [\Omega]$$

$$R_T = \sqrt{R_1 \cdot R_2}$$

$$\lambda g = \frac{\lambda}{\sqrt{\varepsilon_{rel}}}$$

λ : Free-space Wavelength
ε_r : Relative Dielectric Constant
ε_{rel} : Effective Dielectric Constant

$$\begin{cases} when \quad W/h<1 \\ \varepsilon_{rel}=\frac{\varepsilon_r+1}{2}+\frac{\varepsilon_r-1}{2}\left\{\frac{1}{\sqrt{1+12\frac{h}{W}}}+0.04\left(1-\frac{W}{h}\right)^2\right\} \\ when \quad W/h\geq 1 \\ \varepsilon_{rel}=\frac{\varepsilon_r+1}{2}+\frac{\varepsilon_r-1}{2}\left\{\frac{1}{\sqrt{1+12\frac{h}{W}}}\right\} \end{cases}$$

Design Know-How → Notch Filter

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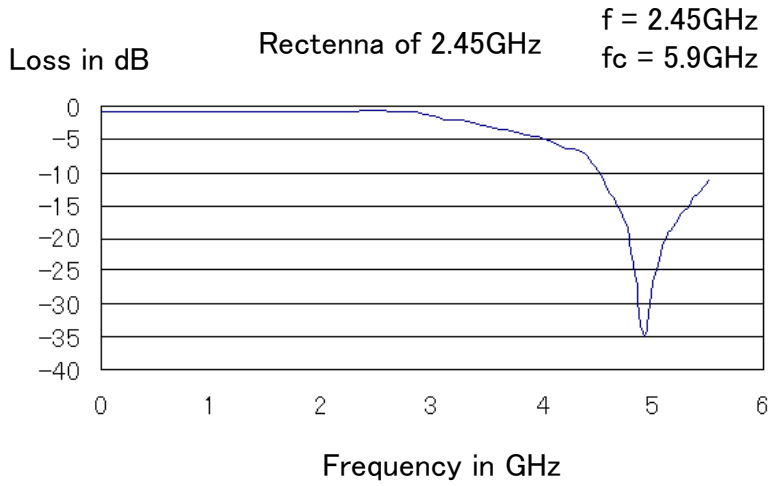

Design Know-How → DC Cut Capacitor

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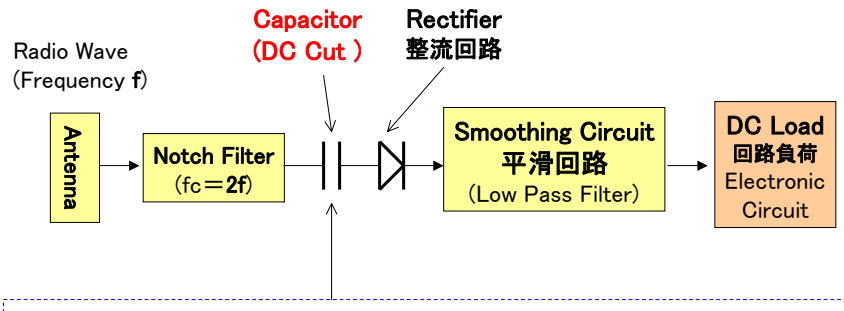

- Choose a Minimum Impedance of Capacitor on the Radio Wave Frequency
- The Minimum Impedance shows on the Self Resonant Frequency of the Capacitor

Design Know-How → DC Cut Capacitor

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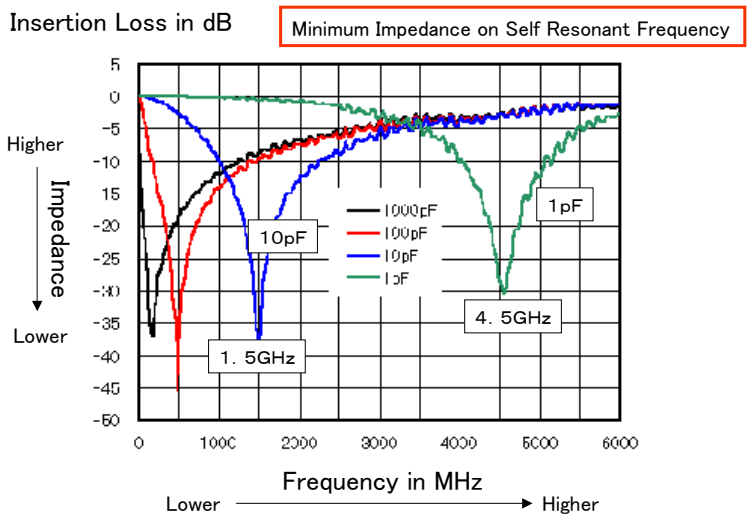

Design Know-How → Rectifier

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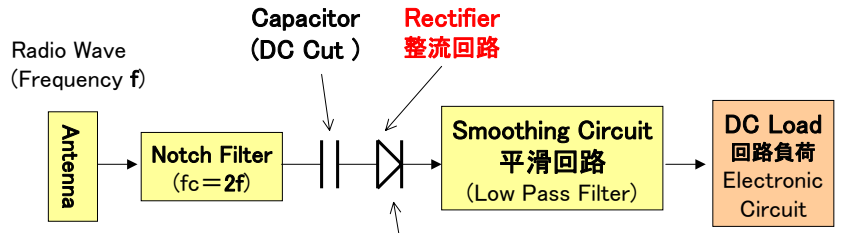

Rectifier for 2.4GHz Detection

1N82G (AMS)	1SS1995(Renesas)
1SS11 (Renesas)	5082-2350(Avago)
1SS97 (Renesas)	5082-2765(Avago)
1SS154 (Renesas)	5082-2824(Avago)
1SS281 (Renesas)	5082-2835(Avago)
1SS1994(Renesas)	HPA2900 (Hawk Power)

• Choose a RF Detection Diode with Small Junction Capacitance

Rectifier for 5.8GHz Detection

MA40150-119 (MACOM)

MA46135-32 (MACOM)

Rectifier for 10GHz & 35GHz Detection

DMK6606 (Alpha)

Design Know-How → Smoothing Circuit (LPF)

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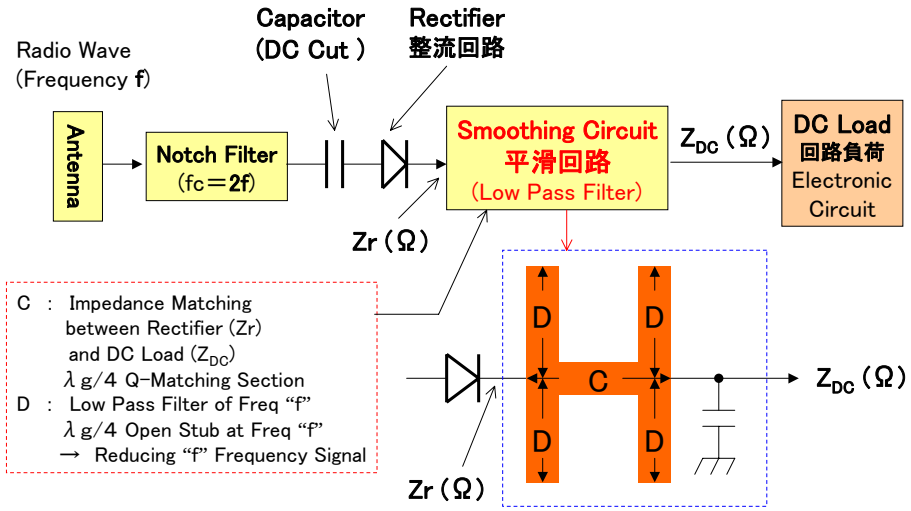

Design Know-How → Smoothing Circuit (LPF)

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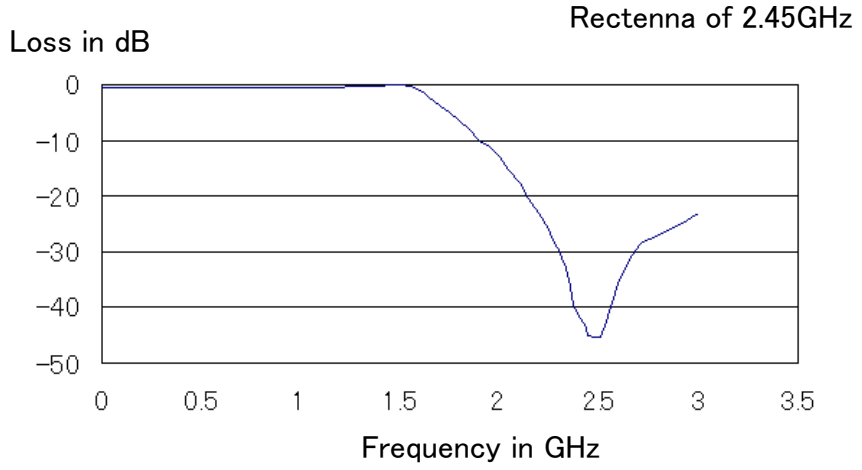
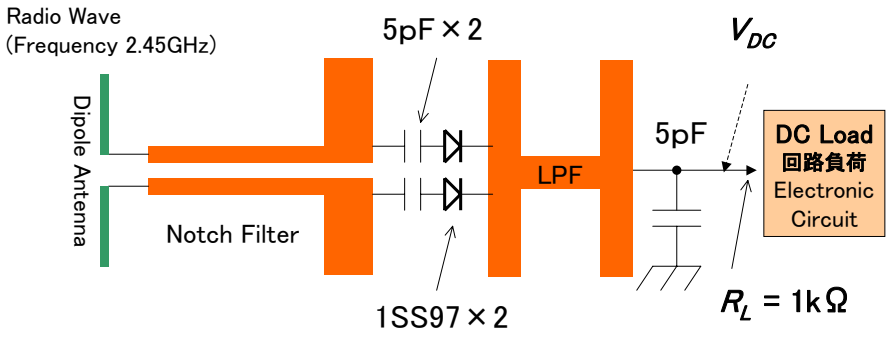
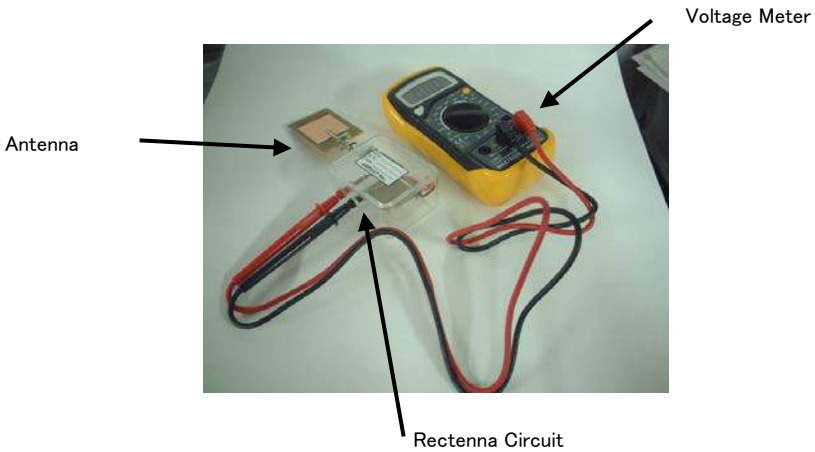


Experiment of 2.45GHz Rectenna Prototype



$$Efficiency: \eta = \frac{Rectenna\_DC\_Output\_Power}{RF\_Input\_Power} = \frac{\left(\frac{V_{DC}{}^2}{R_L}\right)}{P_{RF}}$$

2.45GHz Rectenna Prototype



Efficiency of 2.45GHz Rectenna Prototype

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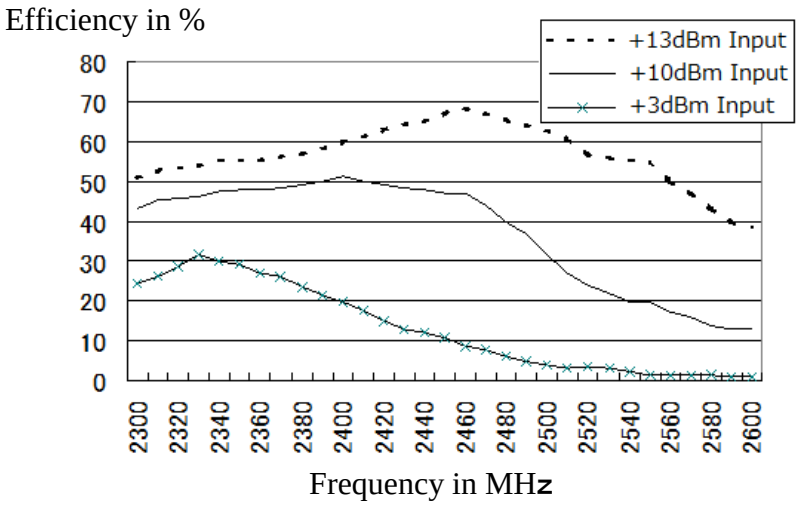

Our Proposed RFID Tag

Our Proposed RFID Tag

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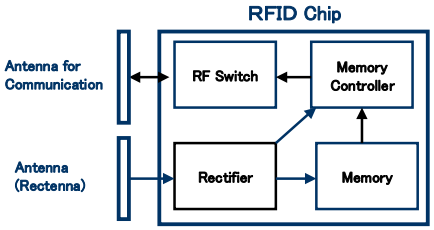
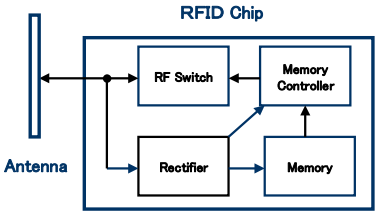


Our Proposed RFID Tag



Other Companies' RFID Tag

As Antenna Design Approach is much different between Antenna for Communication (Refrection RF) and Rectenna (Input RF), we determine to put separate two Antennas. Then we achieved to develop a long range RFID Tag.

Thank you for your attention.

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