

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)

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AMPLET Communication Lab.

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Dr. Nebiya's RFID Books

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1. How does RFID work ?

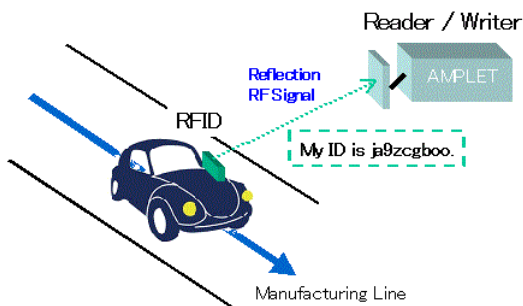
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RFID using Radar Technology

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Reader



RFID Tag

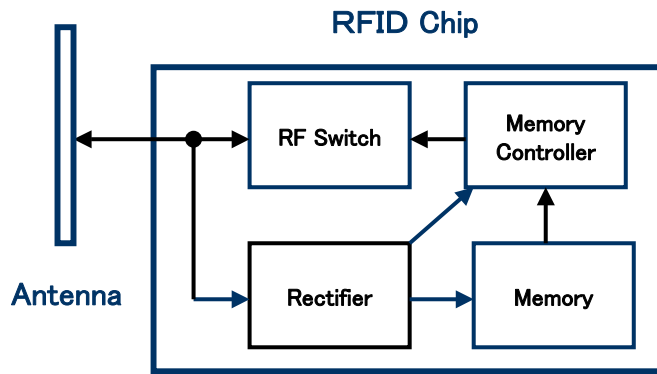
When I moved to Hitachi from Nissan, I considered efficiency of Manufacturing Lines using Radar Technology. Then I invented RFID in 1984.

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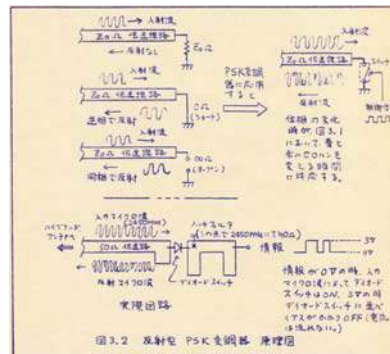
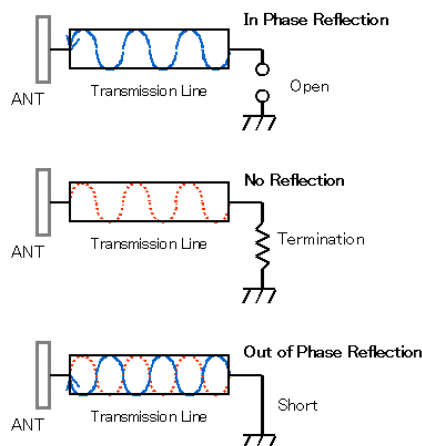
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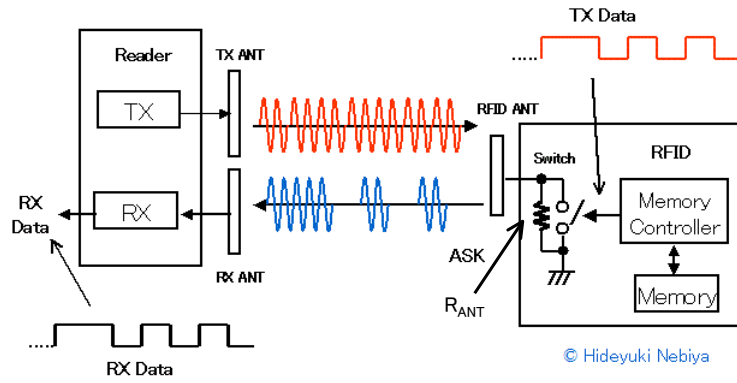
Typical Block Diagram of RFID Tag



Reflection on Transmission Line



Passive ASK RFID

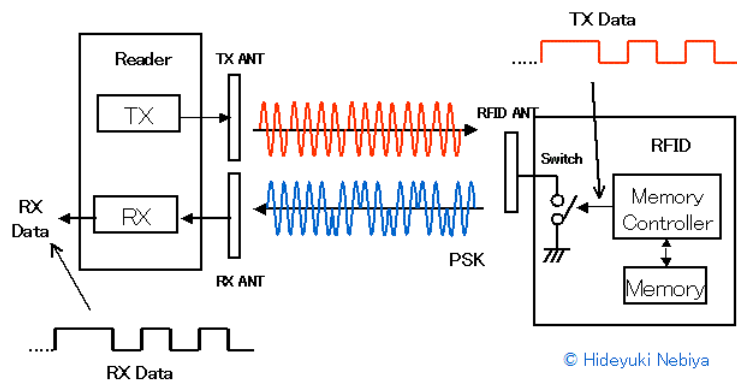


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Passive PSK RFID

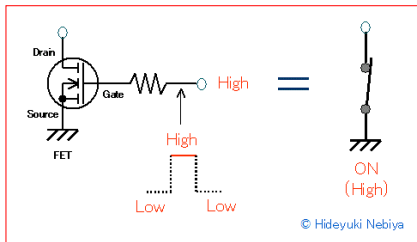


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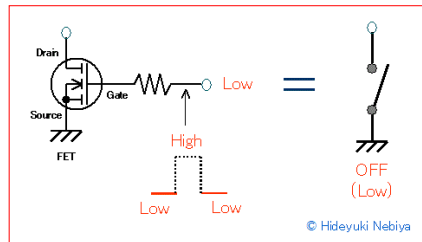
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RF Switch



Switch ON



Switch OFF

2. How to determine Antenna Impedance at RFID Tag ?

In Case of ASK-RFID Tag

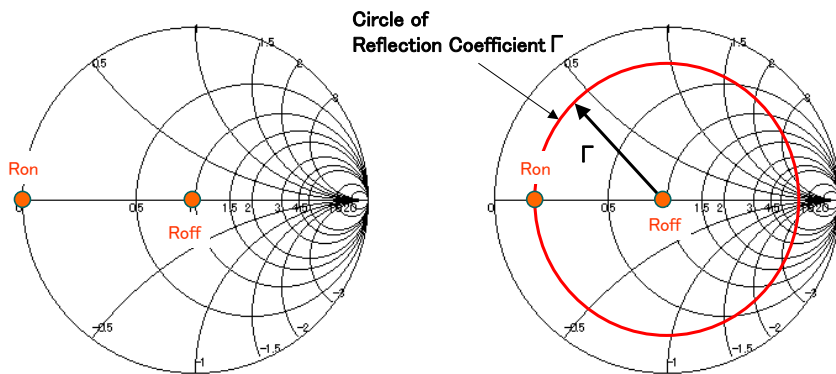
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In Case of ASK-RFID Tag Smithcart normalized for R_{ANT}

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Ideal ASK-RFID
 $R_{on} = 0 \Omega$
 $R_{off} = R_{ANT}$

In Case of ASK-RFID Tag
 $\rightarrow R_{ANT} = R_{off}$

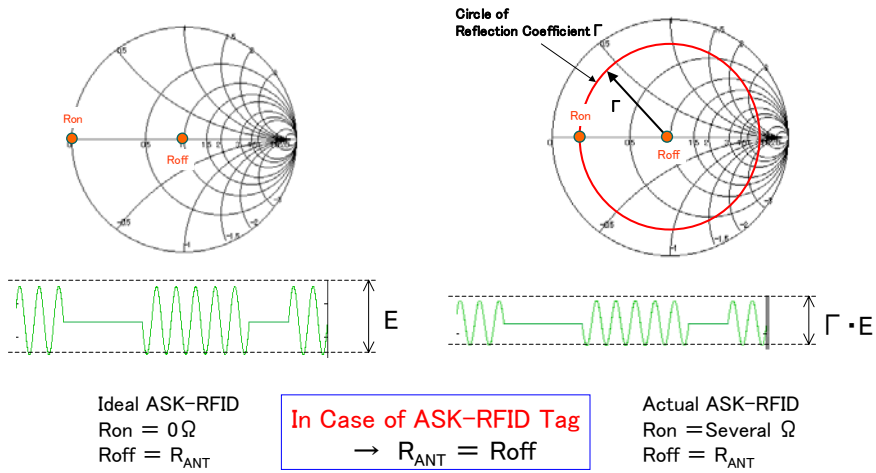
Actual ASK-RFID
 $R_{on} = \text{Several } \Omega$
 $R_{off} = R_{ANT}$

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



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In Case of PSK-RFID Tag

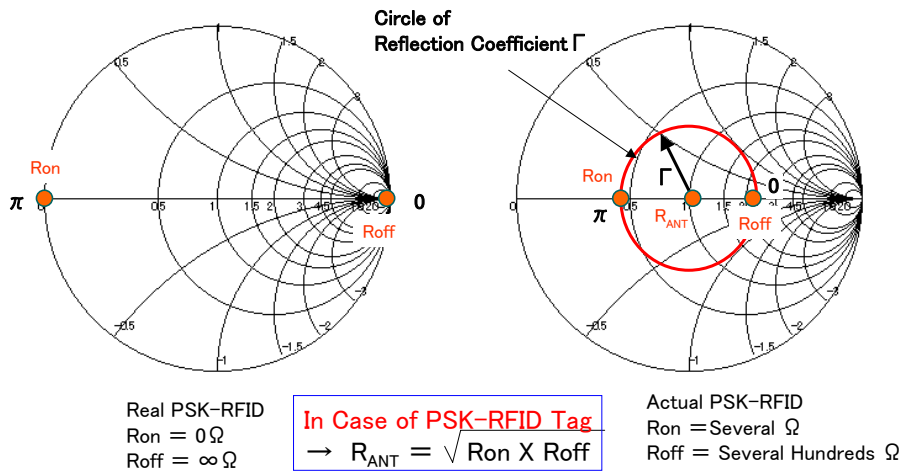
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In Case of PSK-RFID Tag Smithcart normalized for R_{ANT}

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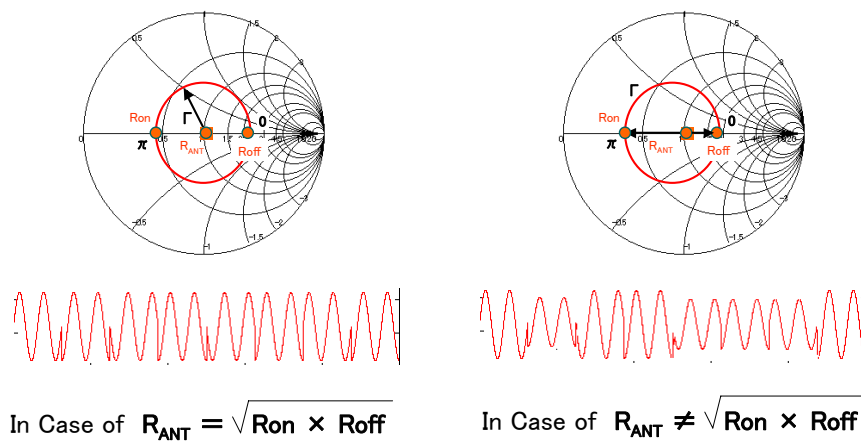
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In Case of PSK-RFID Tag Smithcart normalized for R_{ANT}

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3. Rectenna (Rectifier + Antenna)

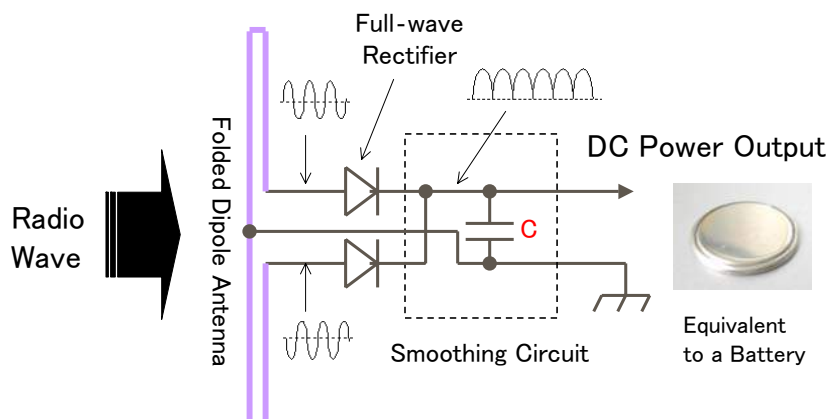
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About Rectenna

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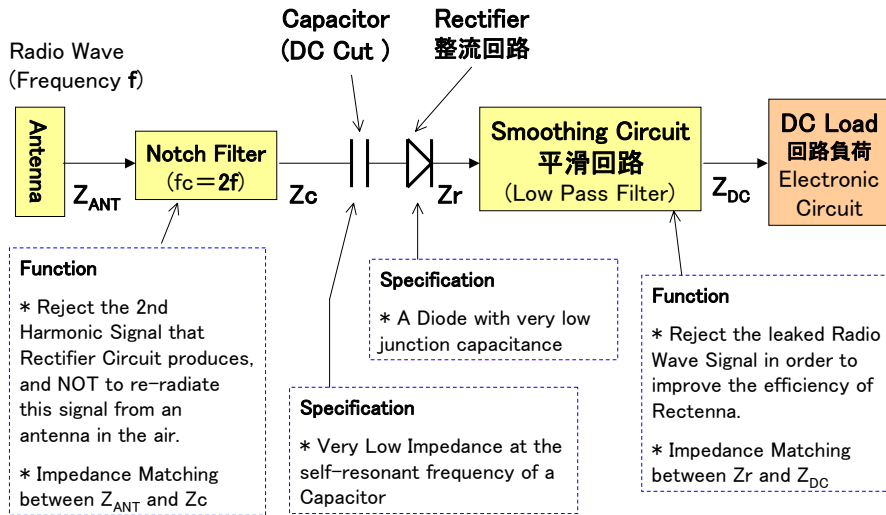


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Block Diagram of Rectenna

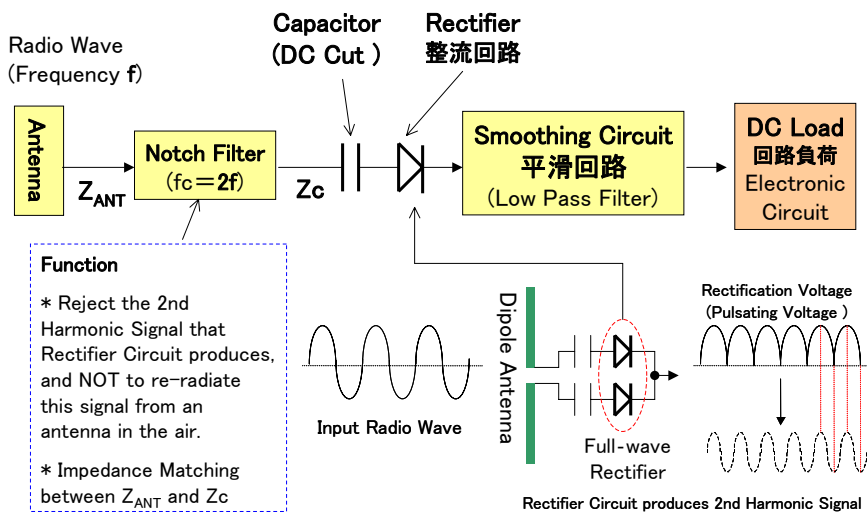


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Design Know-How → Notch Filter



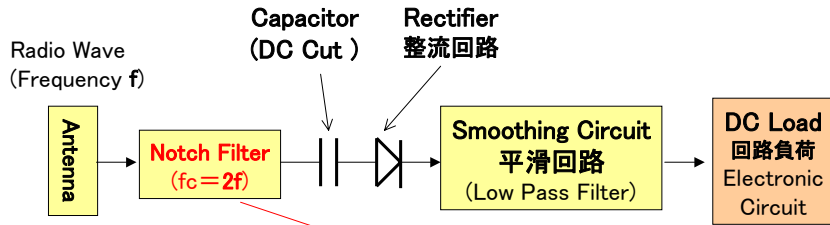
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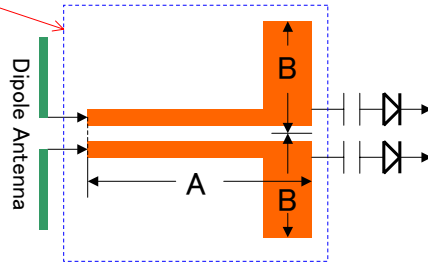
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Design Know-How → Notch Filter

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- A : Impedance Matching of Freq "f"
 $\lambda g/4$ Q-Matching Section
 → Impedance Matching at Freq "f"
- B : Notch Filter of Freq "2f"
 $\lambda g/4$ Open Stub at Freq "2f"
 → Rejecting "2f" Frequency Signal



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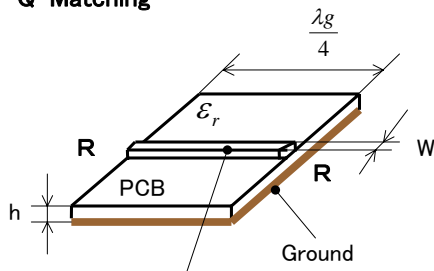
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Impedance Matching (Quarter-Wavelength Matching)

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Q-Matching



$\lambda g/4$ Transmission Line
 Characteristic Impedance = R

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

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

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

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

$$\left\{ \begin{array}{l} \text{when } W/h < 1 \\ \epsilon_{rel} = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2} \left\{ \frac{1}{\sqrt{1 + 12 \frac{h}{W}}} + 0.04 \left(1 - \frac{W}{h}\right)^2 \right\} \\ \text{when } W/h \geq 1 \\ \epsilon_{rel} = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2} \left\{ \frac{1}{\sqrt{1 + 12 \frac{h}{W}}} \right\} \end{array} \right.$$

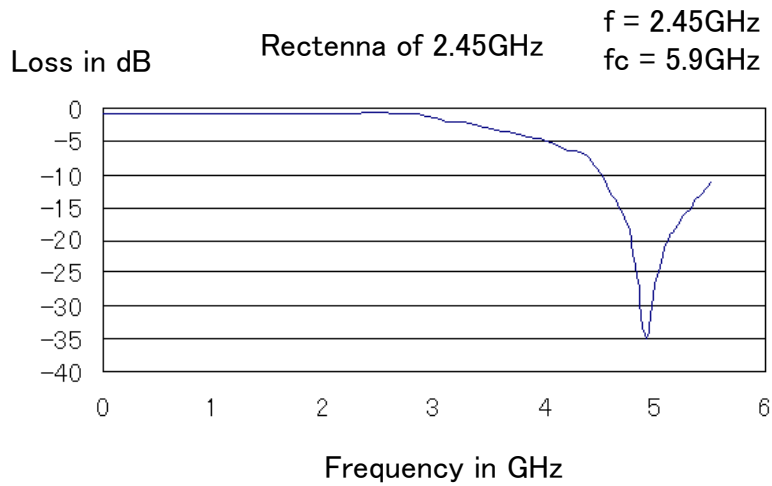
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Design Know-How → Notch Filter

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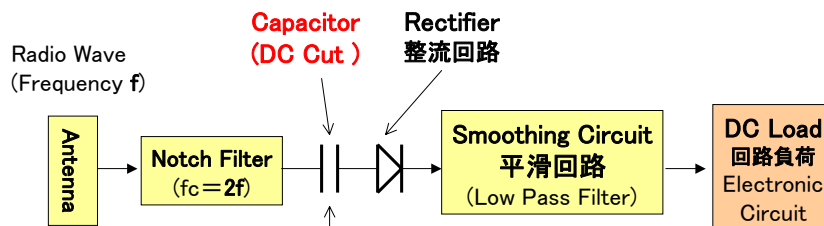
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Design Know-How → DC Cut Capacitor

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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

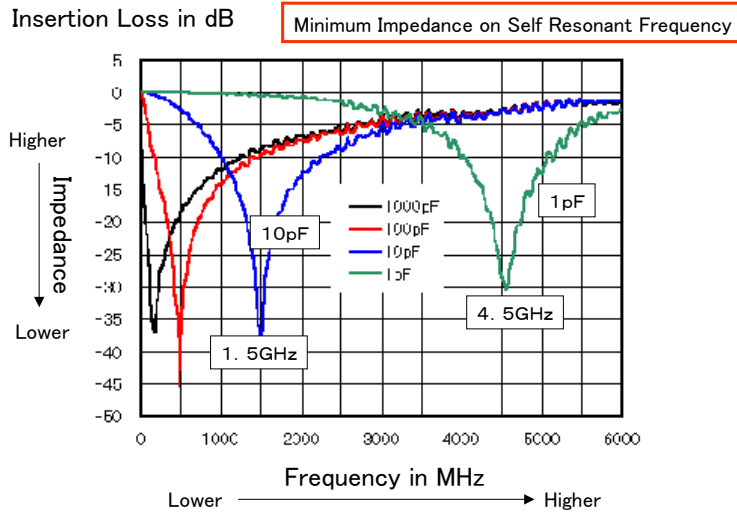
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Design Know-How → DC Cut Capacitor

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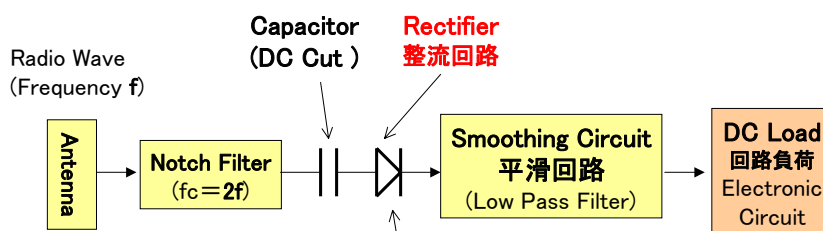
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Design Know-How → Rectifier

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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)

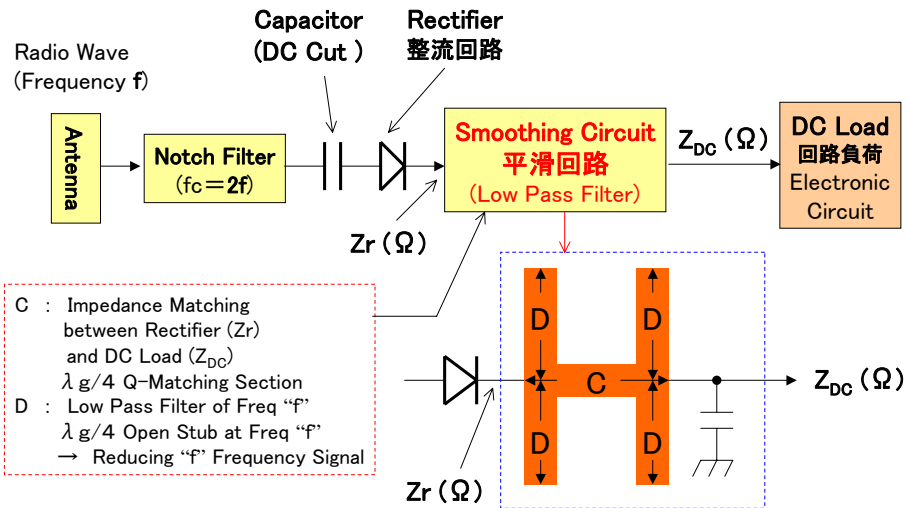
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Design Know-How → Smoothing Circuit (LPF)

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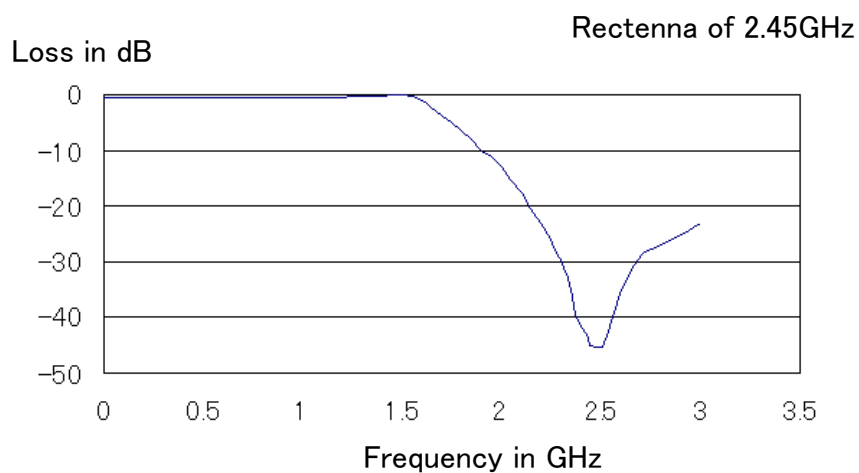
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Design Know-How → Smoothing Circuit (LPF)

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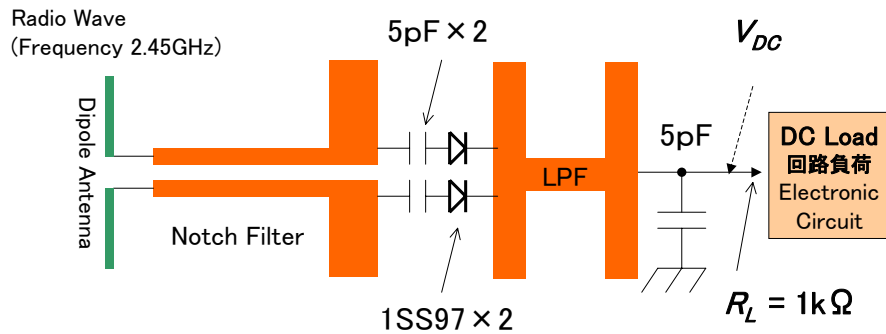
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Experiment of 2.45GHz Rectenna Prototype

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$$\text{Efficiency} : \eta = \frac{\text{Rectenna_DC_Output_Power}}{\text{RF_Input_Power}} = \frac{\left(\frac{V_{DC}^2}{R_L} \right)}{P_{RF}}$$

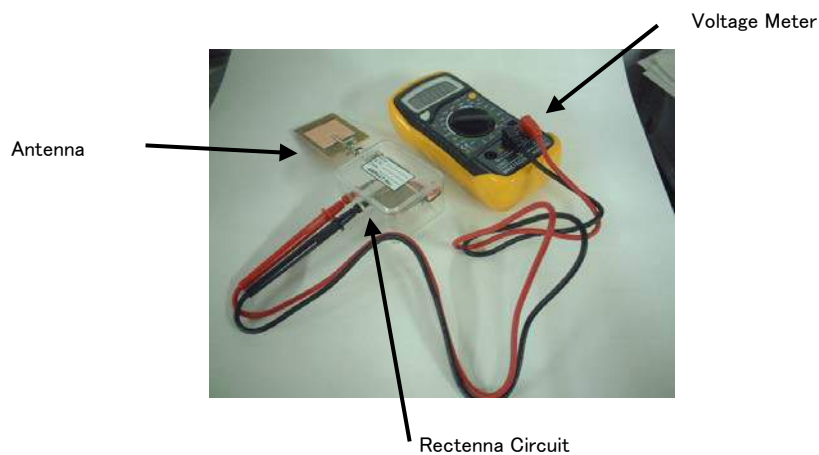
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2.45GHz Rectenna Prototype

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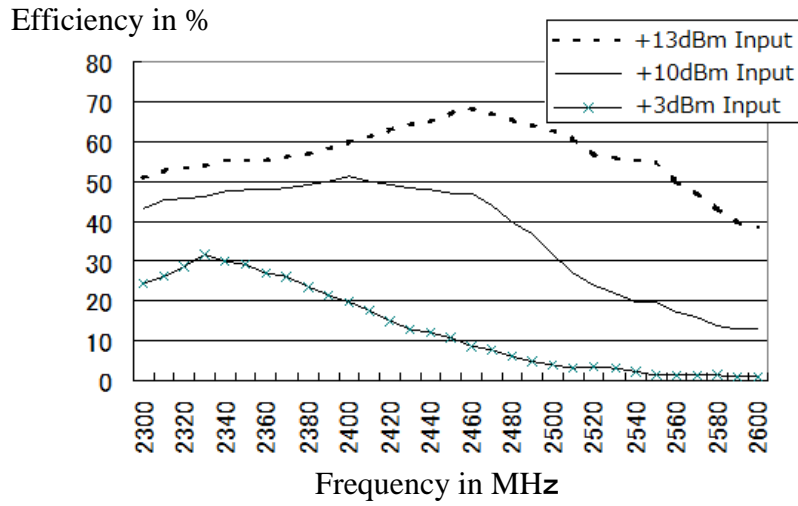
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Efficiency of 2.45GHz Rectenna Prototype

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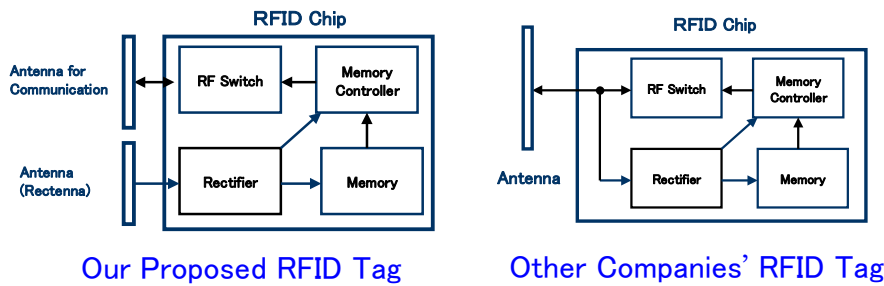
Our Proposed RFID Tag

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Our Proposed RFID Tag



As Antenna Design Approach is much different between Antenna for Communication (Refraction 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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