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Submission Title: [IG DEP Maximizing Power Supply Efficiency with Amplification in Relay Nodes for Multi-hop Relay Wireless Power Transmission]

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Abstract: [To keep dependability of wireless networks, wireless power transmission(WPT) is keen to sustainable operation. This presentation is a solution for micro wave WPT for long distance using multi-hop relay. Optimal number of hops and other schemes are described in WPT performance.]

Purpose: [information]

Maximizing Power Supply Efficiency with Amplification in Relay Nodes for Multi-hop Relay Wireless Power Transmission

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1. Background

◆ **WPT of microwave transmission scheme**

In the case of long distances, the amount of power supply will be a small

→need to reduce the transmission distance between nodes

◆ Purpose of my study

- Applying ICT to WPT

→Enable long distance power transfer

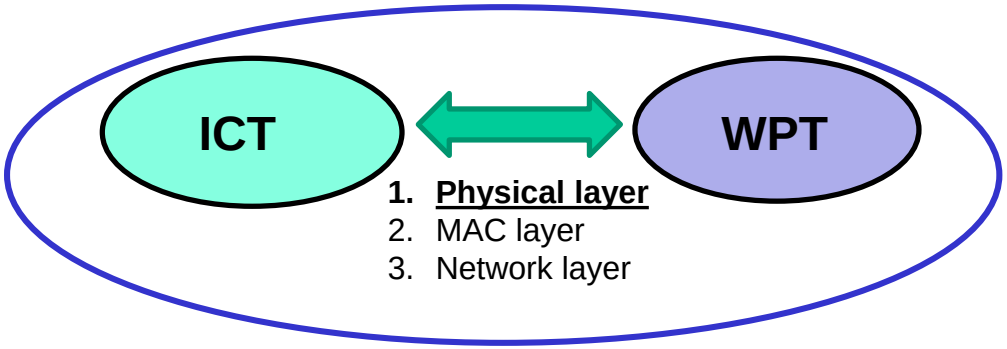


Fig1. microwave transmission

2.1 Proposal Multi-hop Relay System

Multi-hop Relay WPT System

Reduce attenuation and improve power supply by placing a RS(relay node) between transmission

✓ Conventional method

attenuation by direct power transmission

✓ Proposal method

RS(relay node) losses and attenuation between repeaters

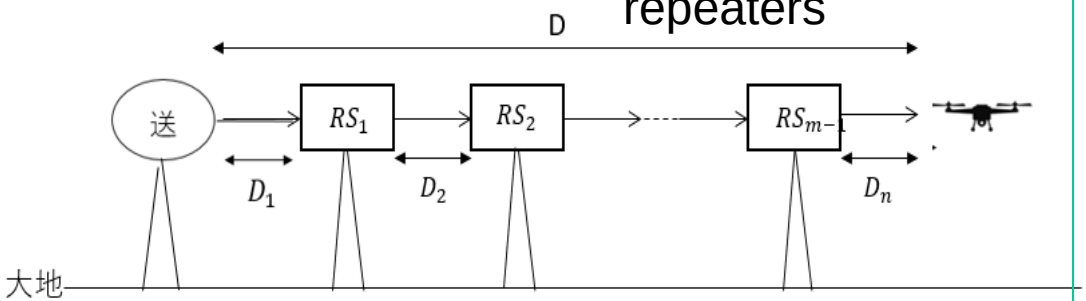
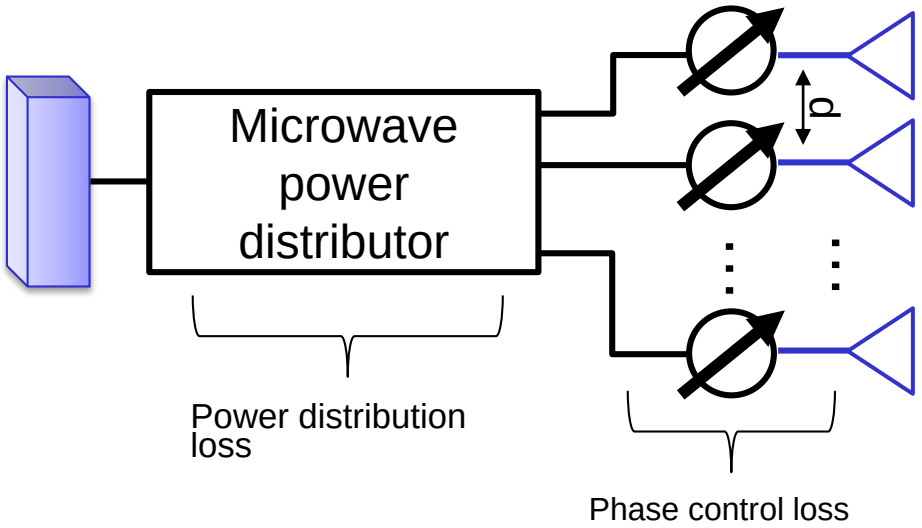


Fig2. system model

✓ System model

- Assume free space propagation
- Transmission power of each node is the same
- Each node is equally spaced
- Transmitter uses linear array antenna
- Transmitter fixed
- Antenna are confrontation

2.2 Distribution and Forward Scheme



Distribution and forward scheme

- Do not convert microwave received power into direct current
- Microwave power is directly distributed by the distributor, and the phase is controlled and transmitted from the antenna.

Merit

- Less power loss at relay nodes because power is not converted to direct current

Demerit

- Because the relay node does not receive power, the flight time of the relay node is not improved

In this study, we use this method

2.3 End to End Power Efficiency

Derived using Friis formula (near field considerations). Number of relay nodes : (m-1)

Distance attenuation between repeaters in the case of near field. m times.

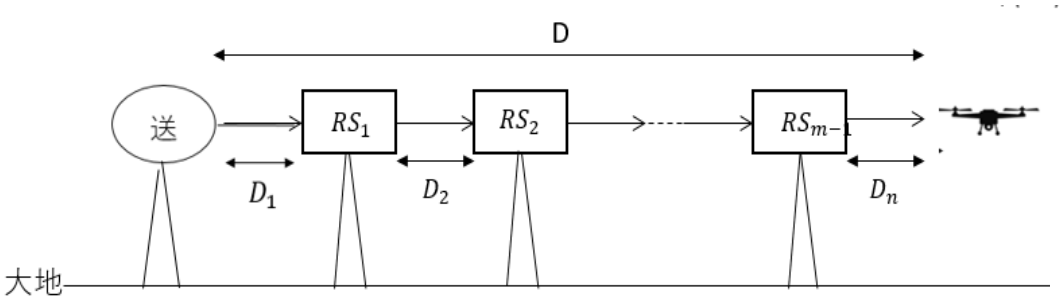
Relay node loss is (m-1) times.

Power conversion efficiency

$$給電量=P_0(1-e^{-\frac{A_tA_r}{\lambda^2D_1^2}})\cdot(1-e^{-\frac{A_r^2}{\lambda^2D_2^2}})\cdot\ \ldots(1-e^{-\frac{A_r^2}{\lambda^2D_m^2}})\cdot LOSS^{m-1}\cdot PCE$$

$$=\frac{P_0\cdot\mathrm{PCE}(1-e^{\frac{-A_tA_r}{\lambda^2D_i^2}})}{LOSS}\prod_{i=2}^{m}(1-e^{\frac{-A_r^2}{\lambda^2D_i^2}})\ \mathrm{LOSS}$$

P_0: Transmitted power of Tx
LOSS: LOSS rate of relay node
PCE: Power conversion efficiency
A_t : Aperture size of transmitting antenna A_r : Aperture size of received antenna



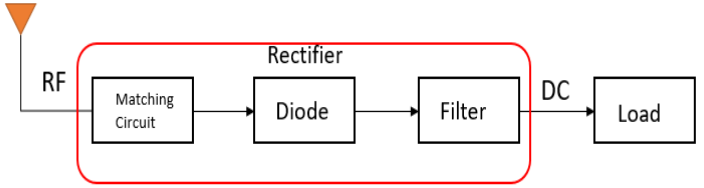


fig3. Rectenna structure

2.4 Simulation Parameters

table1

Height from the ground h[m]	3
Total distance D[m]	10
Aperture size of transmitting antenna $A_t[m^2]$	0.4
Aperture size of receiving antenna $A_r[m^2]$	0.4
Power conversion efficiency PCE	0.84
LOSS rate of relay node	0.8
Transmit power [W]	100
f[GHz]	2.4

Evaluation index

Amount of power supply(n>2)

$$=\frac{P_0 \cdot \mathrm{PCE}\left(1-e^{\frac{-A_t A_r}{\lambda^2 D_i^2}}\right)}{LOSS} \prod_{i=2}^{n+1}\left(1-e^{\frac{-A_r^2}{\lambda^2 D_i^2}}\right) \mathrm{LOSS}$$

2.5 Power Supply

- In the case of changed the number of repeaters from 0 to 9

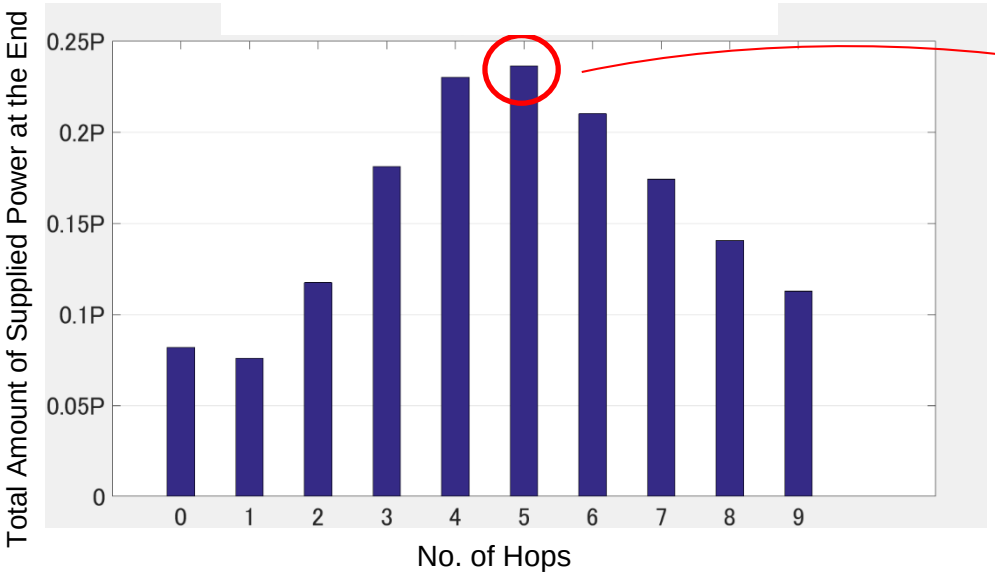


Fig4 . the number of hops vs the amount of power(D=10,LOSS=0.8)

There is an optimal number of hops.

Amount of power supply(n>2)

$$=\frac{P_0 \cdot \mathrm{PCE}\left(1-e^{\frac{-A_t A_r}{\lambda^2 D_i^2}}\right)}{LOSS} \prod_{i=2}^{n+1}\left(1-e^{\frac{-A_r^2}{\lambda^2 D_i^2}}\right) \mathrm{LOSS}$$

P_0: Amount of power supply by total source
LOSS: Loss of repeater
PCE : Conversion efficiency of rectenna
A_t : Transmitter antenna aperture size
A_r : Repeater antenna aperture size

2.6 Optimal Number of Hops

- In the case of changing the loss and total distance

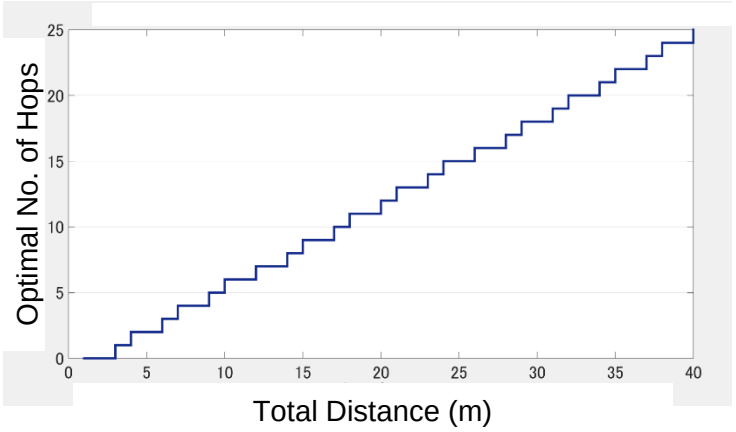


Fig5. D vs optimal hop(LOSS=0.9)

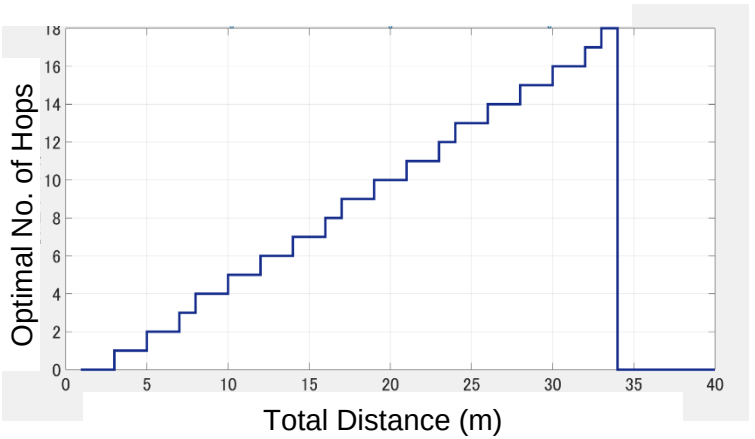


Fig6. D vs optimal hop(LOSS=0.8)

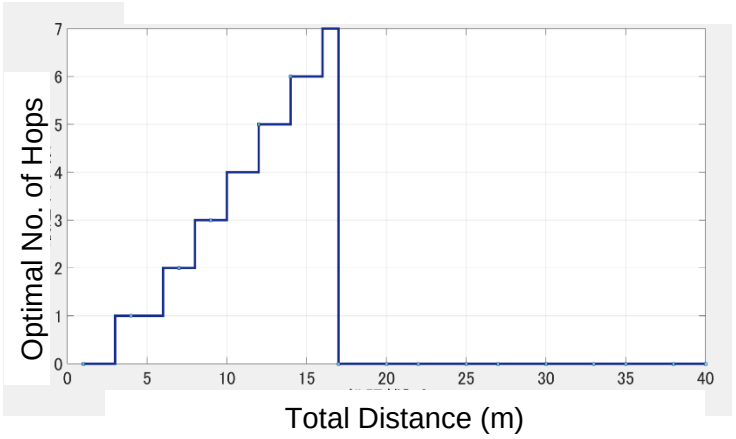


Fig7. D vs optimal hop(LOSS=0.7)

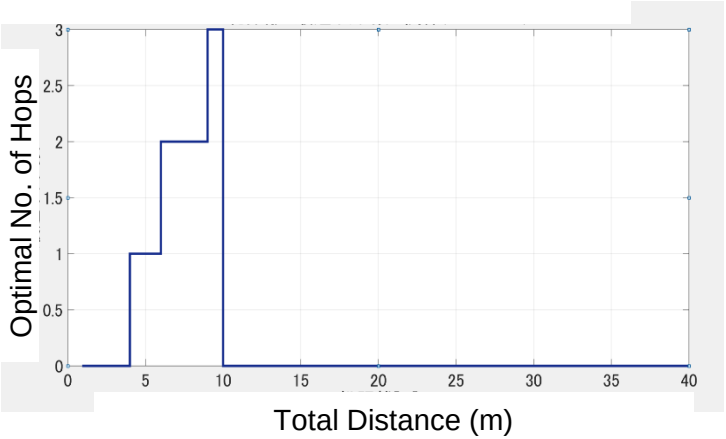


Fig8. D vs optimal hop(LOSS=0.6)

3.1 Improved Method Using Additional Power Supply in a Relay Node

- Improved method

RS have ET (Energy Transmitter) function, and power is amplified by the RS

→Make it possible to supply far.

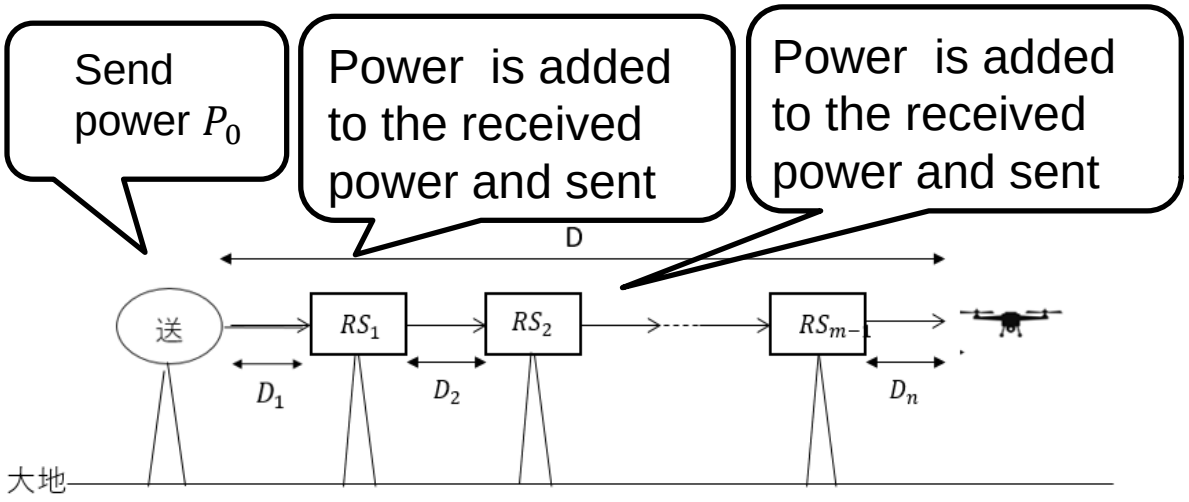
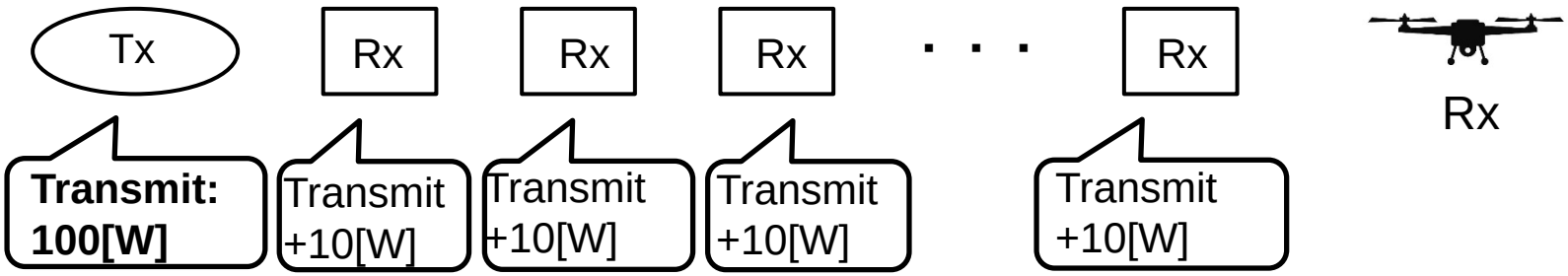


Fig8. improved method

- The amount of amplification is equal
- Others are the same as before improvement

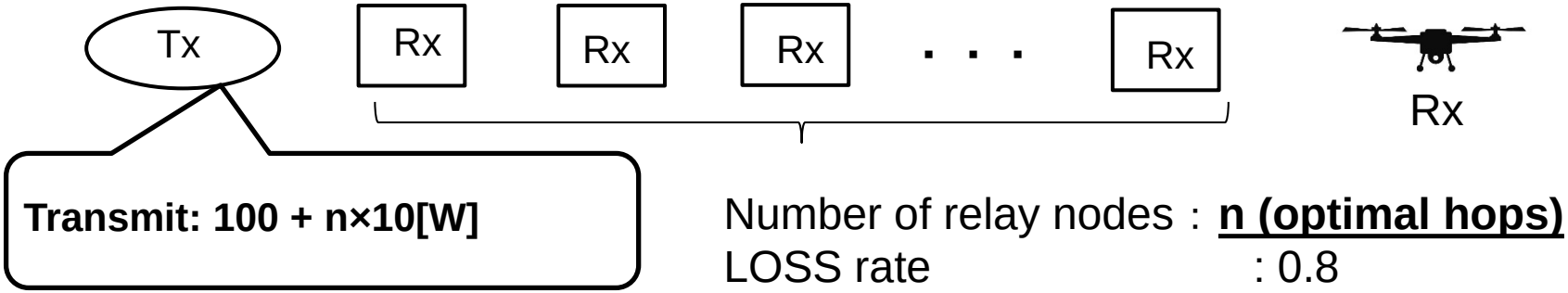
3.2 System model

- Relay amplification



The total transmission power is the same

- Total source amplification



Number of relay nodes : **n (optimal hops)**
LOSS rate : 0.8

3.3 Evaluation(1/2)

✓ Ratio; received power / Total transmitted power

- D=5～30[m] , RS= optimal hops, LOSS=0.8

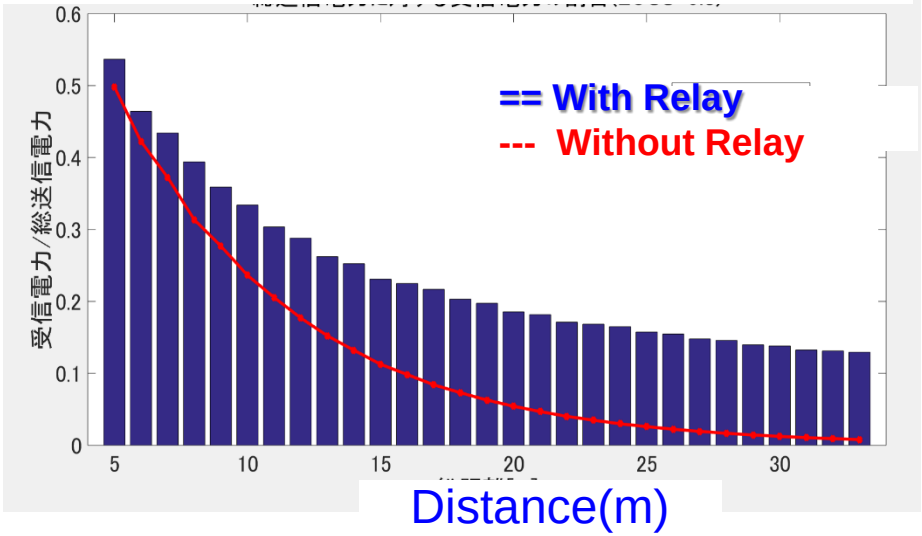


Fig9. relay amplification(D=5～30m,LOSS=0.8)

- D=5～40[m] , RS= optimal hops, LOSS=0.9

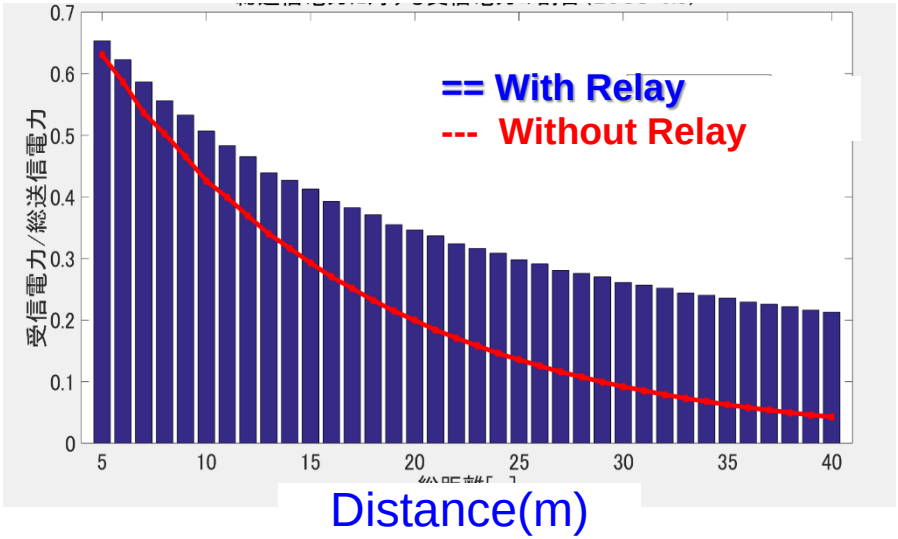


Fig10. relay amplification(D=5～30m,LOSS=0.9)

- Obtained received power / Total transmission power in the case of relay amplification by changing D.
- When relay nodes is amplified ,Received power / total transmission power increased at long distances
- When focusing only on received power, it converged to a certain value.

3.4 Evaluation(2/2)

- ✓ Total Received power at the end while Amplification at relay nodes (Loss=0.9)

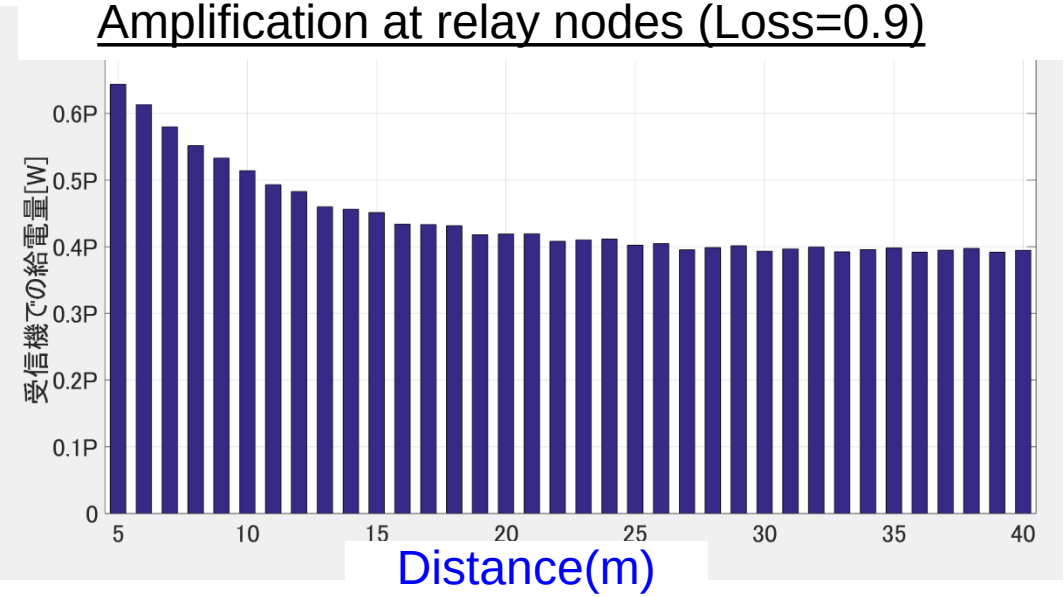


fig11. Received power when relay amplification is used

Received power **converges**

- ✓ Amount of relay amplification is dominant
- ✓ → The power of the Tx has not arrived
- ✓ → Relay amplification is not effective

4. Conclusion

- Systematizing WPT
- Proposal of multi-hop relay method

  →Confirmed that power supply is improved
- Derivation of the optimal number of hops

  → The total distance is divided by approximately 2 meter intervals (LOSS = 0.8)
- Proposed relay amplification for longer distance power transmission

  → Although the amount of power supply has improved,

  relay amplification becomes ineffective when the total distance exceeds a certain value.