Pipe Inspection Robot using Wireless Communication System

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Abstract: Recently many plants become old, and then the pipe lines in the plant also become old. For that reason, it is necessary to develop a flexible pipe inspection robot using wireless communication system. In this research, we have studied the wireless communication system. And we know that the communication system can steadily transfer image data at high speed. Therefore, we developed a new pipe inspection robot with wireless communication system for drain pipe. With this new system, we can control the movement of the robot and inspect the defect or trouble inside the steel pipe or ceramic pipe and also we can transfer the image information inside the pipe in real time.

***Keywords*:** Pipe inspection robot, wireless communication system, image information, real time

I. INTRODUCTION

Recently many plants become old and pipe lines in the plant also become old. In order to inspect and repair these pipes [1], a flexible automotive inspection robot is needed, beside, for controlling the inspection robot and transmitting the collected data to terminal institute, wireless communication system need to be applied together with the inspection robot.

In 2005, radio wave transmission property in steel pipe line had been measured, as for the measurement, if we use wireless LAN with OFDM-2.4GHz or 5.2GHz in the steel pipe, more than 10Mbps information could be transmitted, provide the measured pipe diameter is 20-40cm, and its length within 100m.

Besides, transmission property for ceramic pipe line was also tested, radio transmission property was greatly affected by pollutant, provided the pipe has little pollutant, information data could be transmitted to a long distance.

We have studied the wireless communication system. The wireless communication system can steadily transfer the image data at high speed. Therefore, in this research, we developed a new pipe inspection robot with wireless communication system for drain pipe. With this system, we can control the movement of the robot and inspect the defect or trouble inside the steel pipe or ceramic pipe, and also we can transfer the image information inside the pipe in real time.

II. PIPE INSPECTION SYSTEM

1. Transmission Test in the Steel Pipe

Steel pipe with 30cm diameter and 10 m length is shown in Fig.1. The transmission loss from transmitting antenna input to receiving antenna output is $14 \pm 6dB$ in 2.4GHz band (as Fig.2 shown), $23 \pm 7dB$ in 5.2 GHz band (as Fig.3 shown). So we can transmit [2].

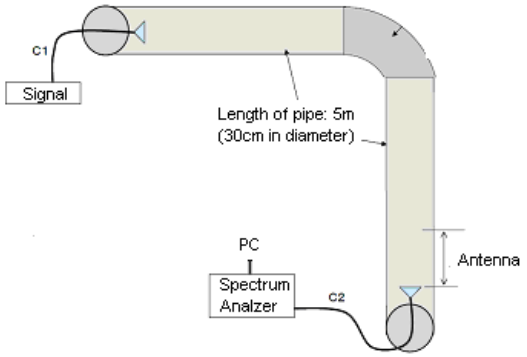

Fig.1. Wireless communication property measurement in the steel pipe

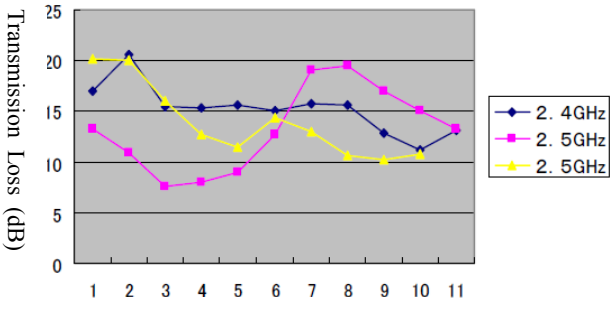

Fig.2. Wireless communication property (Transmission Loss) in Steel Pipe (2.4 GHz)

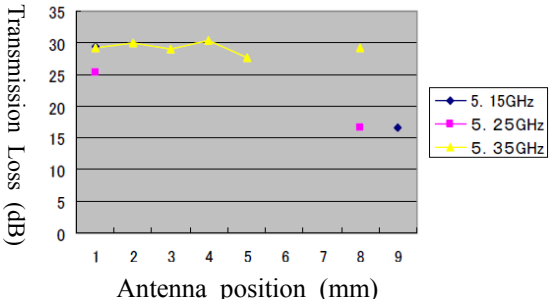

Fig. 3 Wireless communication property (Transmission Loss) in Steel Pipe (5.2 GHz)

2. Transmission Test in the Ceramic Pipe

As for the ceramic pipe with 25cm diameter and 7m length(as shown in Fig.4), the transmission loss was $84 \pm 2.5dB$ in 2.4GHz band, $52 \pm 1.5dB$ in 5.2GHz. Fig.5 shows the relative electric field strength between ceramic pipe and free space. 5.2Ghz band have a good performance in ceramic pipe.

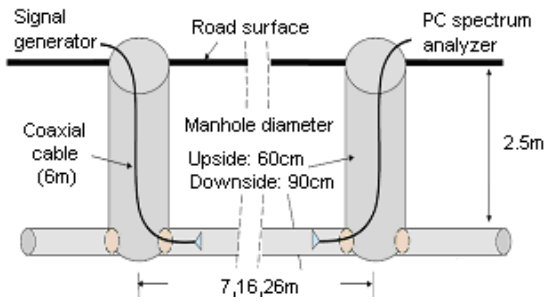

Fig.4. Wireless communication property measurement in the ceramic pipe

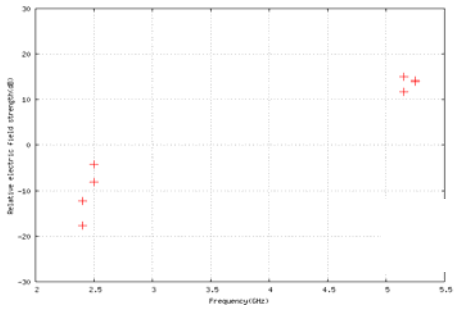

Fig.5. Wireless communication property Result in Ceramic Pipe

III.ROBOT TEST AND TRANSMISSION LOSS MEASUREMENT

We did robot test and transmission loss measurement in actual drain pipe at Yahata in Kitakyushu city in 2007.

1. Robot Test

The wireless robot could run inside the pipe with 20m length and transmitted the inside image data in real time.

Fig.6 shows pipe inspection robot system.

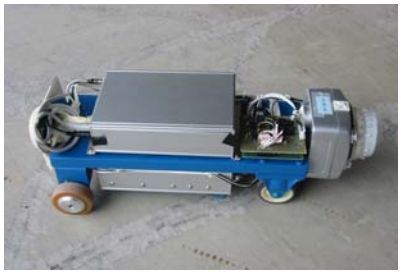

Fig.6. Pipe inspection robot system

2. Transmission Loss Specification

Specifications of transmission loss are explained as the following:

- Measured frequency: 5.25GHz,
- Transmit output: 17dBm,
- Receiver antenna: each 13dBi, total 26 dB,
- Receive cable loss: 6dB.

Fig.7 shows date transmitting and receiving schematic system.

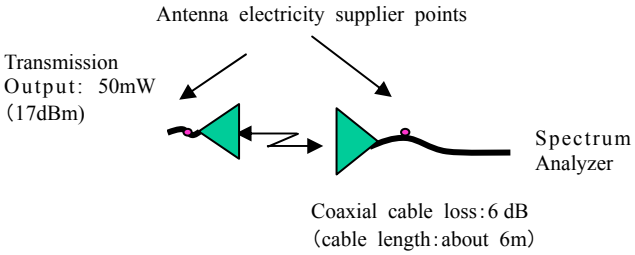

Fig.7. Transmit and receive theoretical schematic

3. Transmission Loss Measurement

The measurement is conducted under the following conditions:

The pipe is ceramic pipe, and well cleaned,

The pipe length is 19m,

There are two type ceramic pipes with different diameter as 25cm and 30cm.

Fig. 8 is the schematic diagram for transmission loss measurement system.

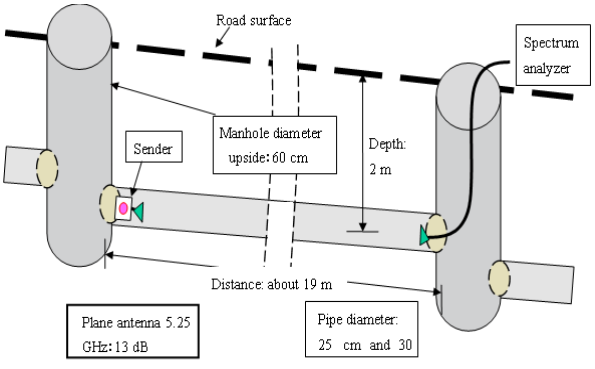

Fig.8. Transmission loss measurement system

4. Measurement Results

Measured data were processed with different method, transmission loss and the approximate equation for 25cm and 30cm diameter pipe are shown in Fig.9, and Fig.10 shows the transmission loss between antenna points, which is measured on the desk indoors.

As for these figures, it is found that transmission loss can be explained using approximate linear equation.

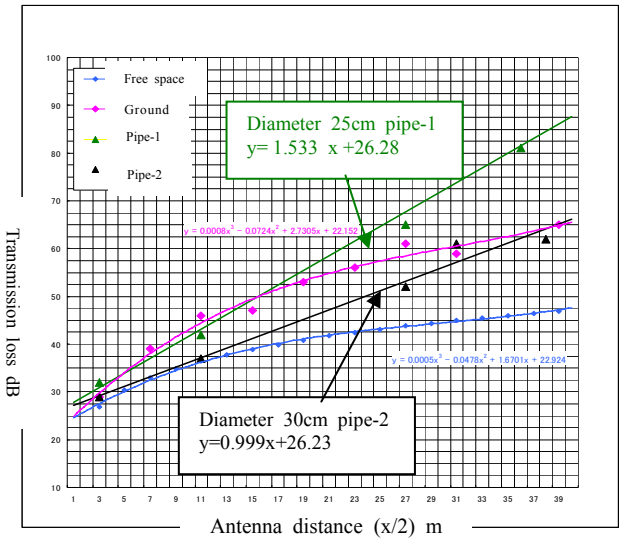

Fig.9. Transmission property

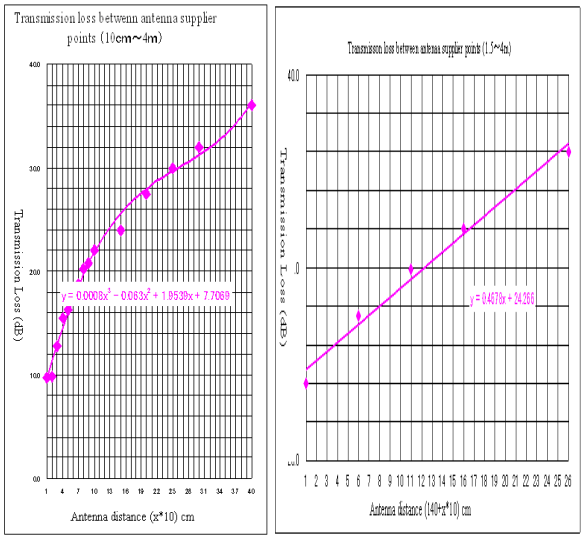

Fig.10. Transmission loss between antenna points

5. Result Discussion

(1) Considering the ground transmission property, measured result in close range, and error, we can use approximate equation in Fig.9 to predict transmission loss in pipe.

(2) The measured data is arranged to Table.1.

Table.1. Approximate Transmission Loss in Pipe line

distance (m)	transmission loss (dB)	
	25cm	30cm
1	27.8	27.2
2	30.9	29.2
5	40.1	35.2
10	55.5	45.2
20	86.2	65.2
30	116.9	85.2

Transmission loss in pipe can be explained by the following equations:

As for diameter 25cm pipe, transmission loss *L:*

$$L = 3.07 \times d + 24.75 \qquad (1)$$

As for diameter 25cm pipe, transmission loss *L:*

$$L = 2.00 \times d + 25.22 \qquad (2)$$

From these equations, it is found that the transmission loss (dB) is proportional to the pipe line length, as shown in Fig.11.

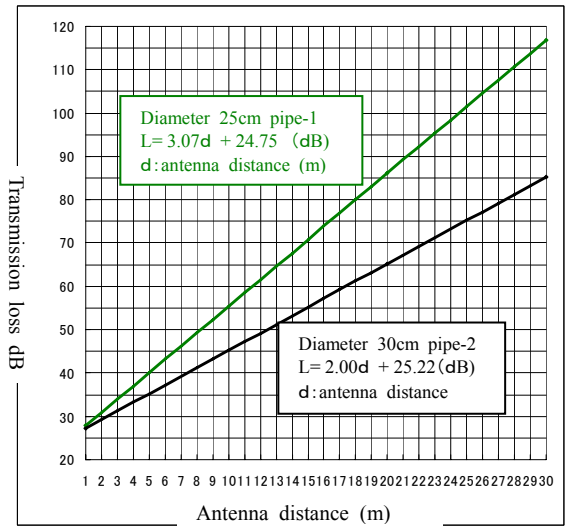

Fig.11. Transmission loss property between antenna electricity supplier points (Antenna distance more than 1m)

(3) Transmission loss property is obtained: if the antenna distance more than 1.5km, transmission loss would increase 3.07dB/m for 25cm diameter pipe, and 2.0dB/m for 30cm diameter pipe.

IV. WIRELESS PIPE INSPECTION SYSTEM

The aforesaid robot inspection system is a testing one, considering real environment, a new robot is applied, besides, wireless communication system would be introduced into the robot, for data transmission and

robot control.

1. Wireless Robot System Diagram

Fig.12 shows the small size wireless robot system.

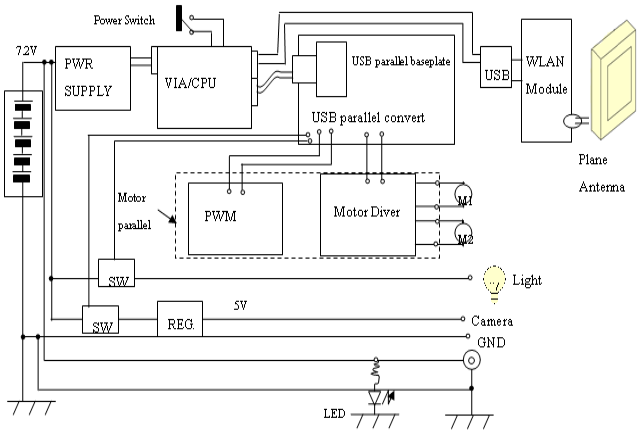

Fig.12. Small size wireless robot system

2. Inspection Robot

The inspection robot applied is Mogurinko by Ishikawa Tekkousyo, as shown below.

Fig.13. Inspection robot (Mogurinko)

Specifications of the inspection robot:

- Moving speed: 13.7m/min,
- Driveling mode: double motor,
- Electric Power: rechargeable batteries 7.2V.
- Wireless frequency: apply to 2.4/5 GHz and Data transmission by 100 base-T Ethernet.

3. Wireless Communication System

There are two type wireless communication system in long distance pipe or manhole.

In order to ensure the information transmission which passes manhole, the two-way amplifier between antennas is introduced (type-1 shown in Fig.14). As for the type-2 wireless communication system (shown in Fig.15), it could realize 200-300m information transmission, besides, it is possible to be applied to mesh cable and parallel two-wire cable.

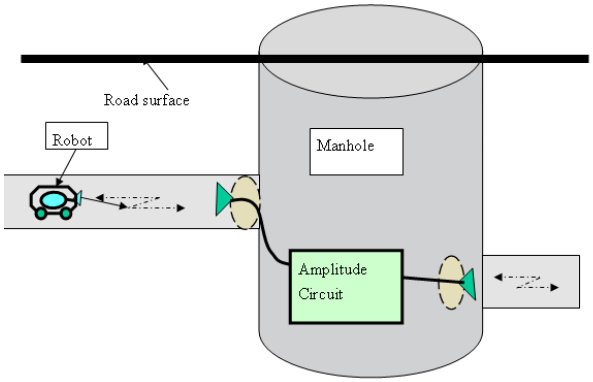

Fig.14. Wireless system type-1(two-way transmission type)

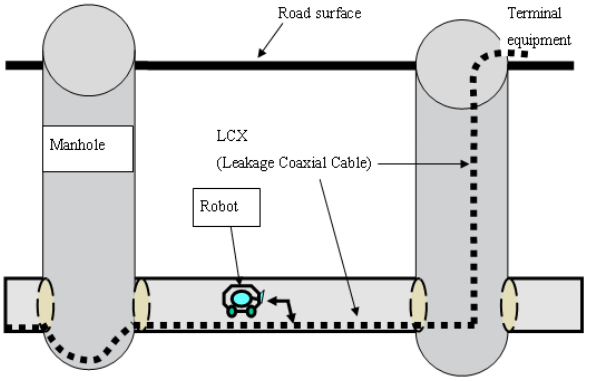

Fig.15. Wireless communication system type-2

V. CONCLUSION

We studied the wireless communication system in the pipe, and developed new robot system which would be used in pipe inspection robot system. We tested transmission loss in ceramic pipe, and got the transmission property.

Because of different pipe materials and service condition, maximum transmission length would be determined for wireless communication system.

REFERENCES

[1] Kosuke Wada (2007), Wireless Radio Communication System for Pipe Inspection Robot and Bridge Diagnosis Data. Waseda University, Master's thesis,

[2] Harutoshi Ogai, Kosuke Wada, Katsumi Hirai, et al (2007), Wireless Radio Communication System for a Pipe Inspection Robot, International Conference on Control, Automation, and System, October 17-20, Korea.