TEST MODEL OF MILLIMETER-WAVE IMAGING RADIOMETER EQUIPMENT (MIRAE)

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ABSTRACT: Millimeter-wave (MMW) imaging radiometer systems have an attractive advantage to obtain an image through low visibility weather conditions such as fog, clouds and light rain compared with visible and infrared imaging systems. Many countries have developed a various kinds of MMW imaging radiometers for the aim of low cost and high performance. In Korea, Millimeter-wave Imaging RAdiometer Equipment (MIRAE) has been developed since the end of 2006. Recently the development of some modules was finished for the test model. This paper describes the design and development of the MIRAE. In addition, the test results of its manufactured modules are presented.

KEY WORDS: Millimeter-wave imaging (MMW), W-band radiometer, focal plane array

1. INTRODUCTION

Millimeter-wave (MMW) radiometer is a sensor system that measures incoherent electromagnetic energy radiated from an object in MMW band. (Skou, 2006; Ulaby, 1986) Its outstanding advantage is to get an image in nasty weather environments, for example, fog, cloud, and rain unlike visible camera and infrared (IR) imaging system. The easiest way to obtain an image is to use fully 2-dimensional (2D) focal plane receiver array without any scanning. However, it is difficult to assemble 2D array and highly costly. To solve the problem, a various types of image acquisition methods have been suggested such as electrical scanning, interferometry, and mechanical scanning. We have been developing a MMW radiometer since 2006. It was named as Millimeter-wave Imaging RAdiometer Equipment (MIRAE). It gets an image by 1D scanning of 1D multi-channels radiometer receiver array operating at W-band. Recently the development of some modules was finished for the test model. In this paper, the MIRAE system requirements, configuration and its subsystem are described, and the test results of manufactured modules are presented.

2. MIRAE SYSTEM

2.1 System Requirements

The propagation of MMW radiation is attenuated by the atmosphere with minima of the most commonly used frequency for MMW imaging occurring at 94 GHz (Gleed, 1997; Ulaby, 1986). Since the required field of view (FOV) and spatial resolution are 17°x17° and 0.57°, an 2D array of receivers is needed to obtain an image simply. However, since 2D array hardware is complex and highly costly, the 1D array with a mechanical receiver scanner was used to get an image. The other requirements for MIRAE development are listed in Table 1.

Table 1. Requirements for MIRAE

Items	Requirements
Frequency Band	W-band
Dynamic Range	40 K ~ 320 K
Sensitivity	≤ 1.5 K
RF Bandwidth	8 GHz
Resolution	10 mrad (0.57°)
FOV	17°(Azimuth), 17°(Elevation)
Radiometer Type	Total power radiometer

2.2 System Configuration

Figure 1 illustrates the MIRAE configuration. MIRAE utilizes quasi-optical imaging through high density polyethylene lens focusing the incoming W-band electromagnetic wave on the feed antennas of multi-channel radiometer receiver on the lens's focal plane. It consists of lens, radiometer receiver subsystem, data processing subsystem and calibration subsystem.

The function of radiometer receiver subsystem is to convert the measured electromagnetic wave from an object into producing a voltage signal. The radiometer subsystem comprises multi-channel receivers and a receiver scanner. The role of data processing subsystem is to display the Millimeter-wave image stream after processing the multi-channel voltage signal. The data processing subsystem includes an image processing unit to handle with multi-channel voltage signals and an image display unit to show the processed image on a monitor. The calibration subsystem includes a mirror to control measurement direction of multi-channel receivers, a mirror controller, and an absorber as a hot source.

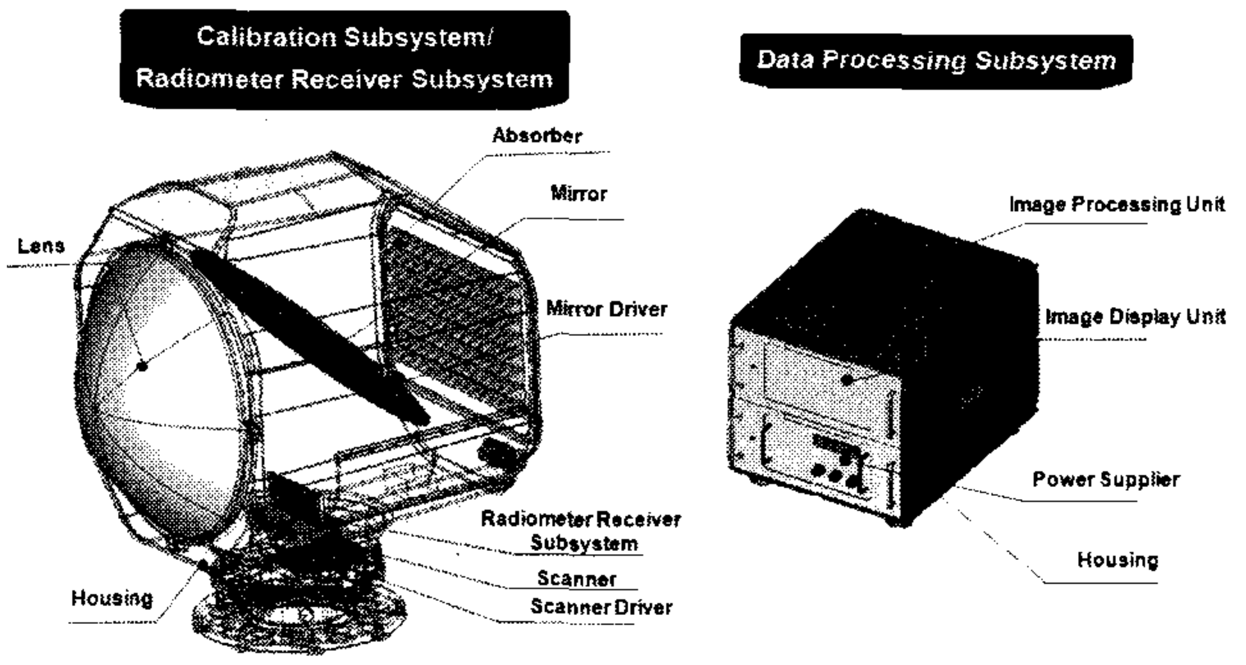

Figure 1. MIRAE System Configuration.

3. MIRAE SUBSYSTEM

3.1 Lens

Lens concentrates the radiant electromagnetic wave (brightness temperature) from a body on its focal plane. The diameter of the lens was determined as 500 mm to satisfy the 0.57° spatial resolution. Figure 2 shows the manufactured lens. It was made of high density polyethylene because of light weight, easy manufacturing, and low attenuation loss.

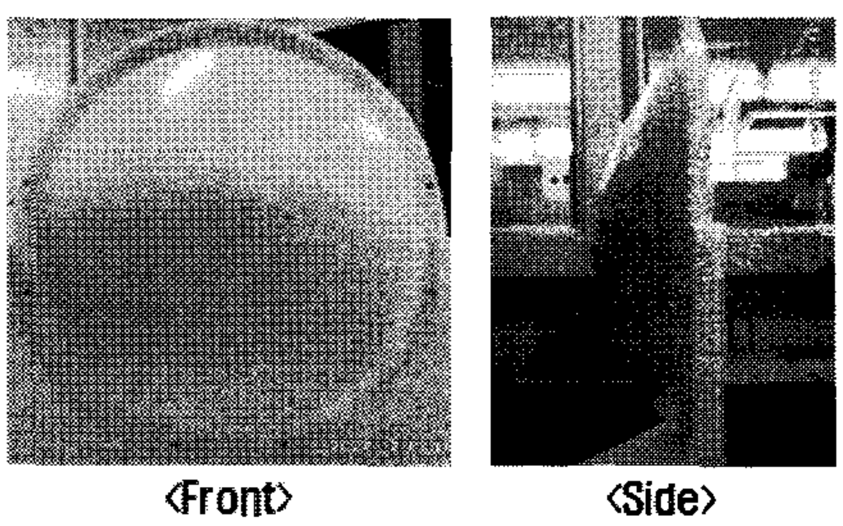

Figure 2. High Density Polyethylene Lens.

3.2 Calibration Subsystem

Calibration subsystem is to make all radiometer receivers maintain uniform performance. It includes a mirror, a mirror driver, and an absorber. The absorber is acted as a hot source. The role of mirror is to switch the mode of the scene measurement or the absorber measurement.

3.3 Radiometer Receiver Subsystem

MIRAE uses direct detection total power type radiometer. The direct detection method is technique to convert RF signal into baseband signal. it has lower conversion loss and lower noise figure compared with superheterodyne, because it does not need a mixer, an IF amplifier, a local oscillator and extra electronic components. Furthermore, its hardware architecture is simpler and smaller. The configuration of total power type radiometer is simpler hardware structure and higher temperature sensitivity than that of Dicke or noise injection type.

Radiometer receiver subsystem contains multi-channel radiometer receivers and a DC-DC conversion unit. Each receiver consists of a feed antenna, a RF amplifier, and a LF unit.

3.3.1 Feed Antenna

The feed antenna sends the current to the RF amplifier after converting the measured electromagnetic energy to the current signal. We designed it to have the maximum energy transfer efficiency between the lens and the feed antenna and to have -10 dB edge tapper to minimize the spillover (Anderton, 2005). Its type is the dielectric rod antenna with polyethylene.

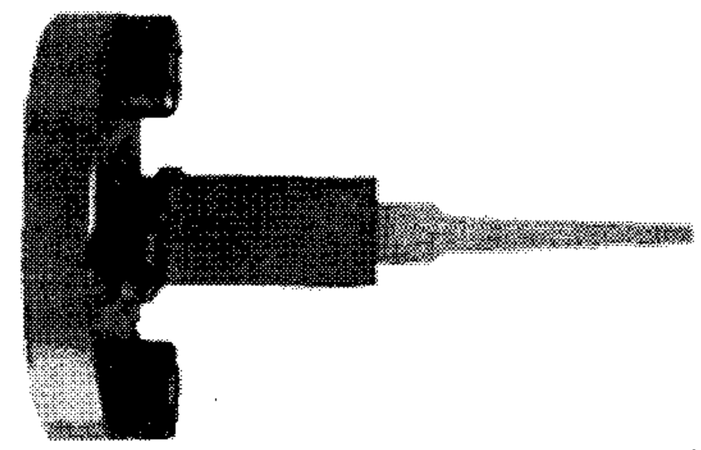

Figure 3. Dielectric Rod Antenna.

Table 2. Antenna Measurement Result

Freq. (GHz)	Gain (dB)	10dB beamwidth (dB)		Sidelobe level (dB)	
		E	H	E	H
94	15.26	53.22	48.59	-16.88	-22.53

3.3.2 RF Amplifier

The design consideration of RF amplifier for the direct detection radiometer receiver was not only to intensify the desired frequency band signal, but also to minimize inherent noise of components included in RF amplifier. The RF amplifier was designed based on four MMIC (monolithic microwave integrated circuit) LNAs (low noise amplifier). In order to prevent the inner oscillation, we made two MMIC LNAs pair up and inserted a band pass filter (BPF) between MMIC LNA pairs. Their arrangement is illustrated in Figure 4. Figure 5 shows the manufactured RF receiver and its gain.

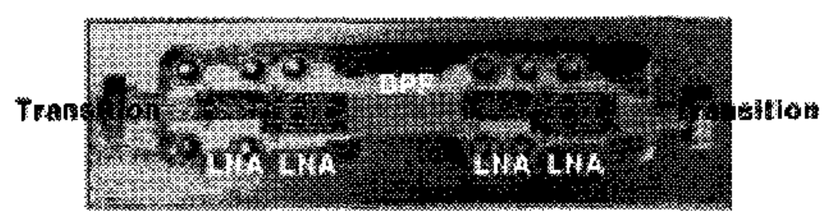

Figure 4. Disposition of MMIC LNA and BPF.

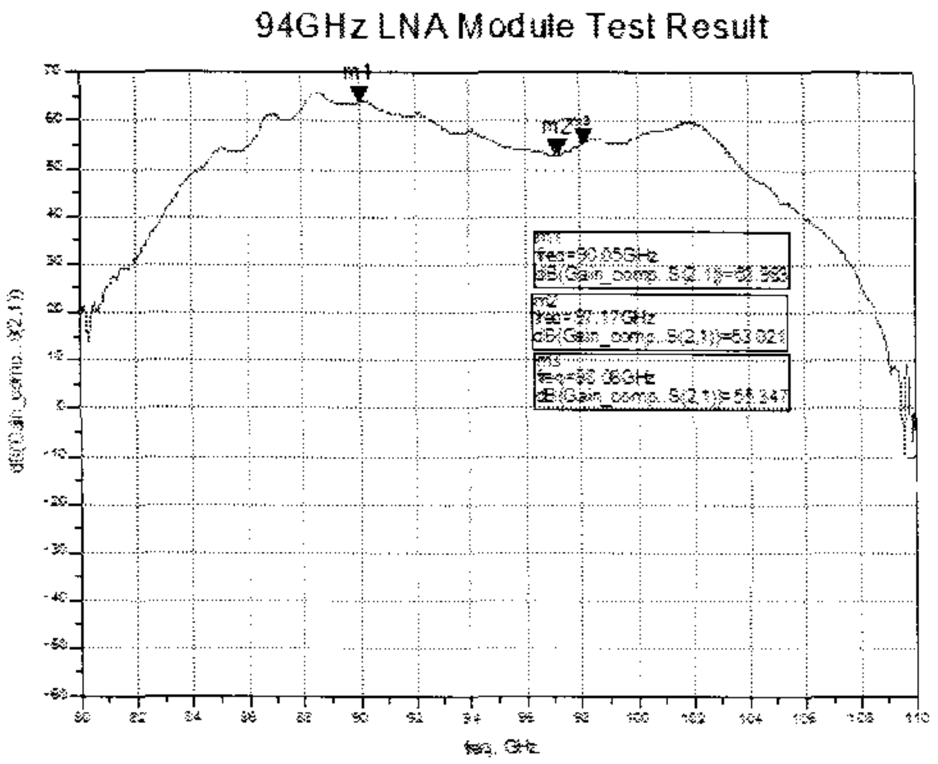

Figure 5. RF Receiver's Gain.

3.3.3 Detector and LF unit

The detector converts the RF signal into the DC voltage signal. The LF unit amplifies the DC voltage signal suitable for A/D converter in the image processing unit because the output voltage of the detector is minuscule as μ V unit. In design of the detector, a point to be considered is that power matching is applied for maximum power transfer of a signal from RF signal to detector's input. The simulated return loss of the detector is less than -15 dB in the desired frequency band.

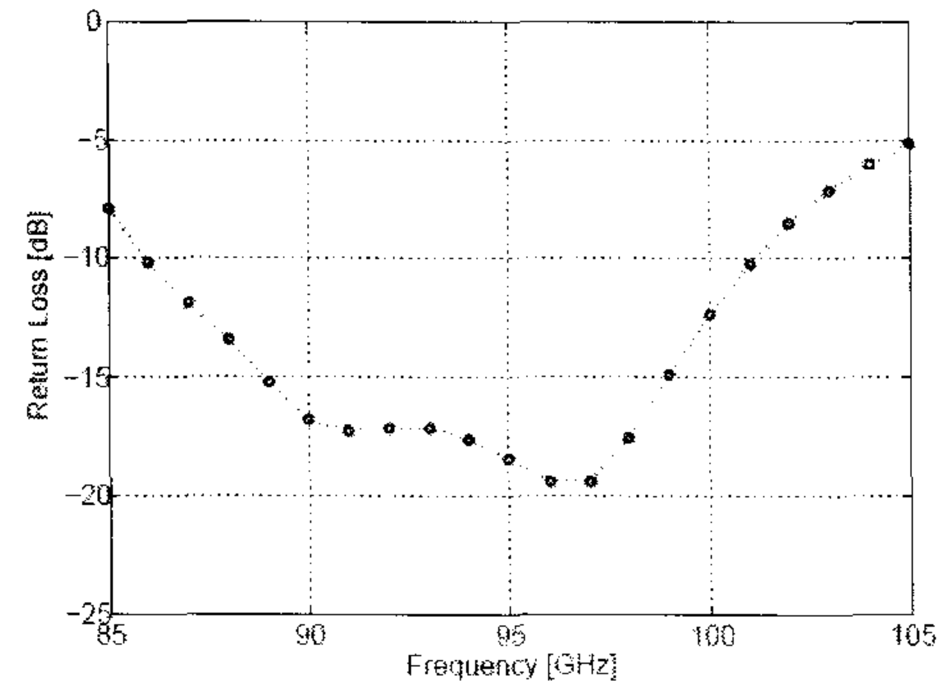

Figure 6. Simulated Result of Detector's Return Loss.

3.4 Data Processing Subsystem

The image processing unit is required to receive multi-channel receiver signals. The image display unit is to perform gray-level scaling and display the processed MMW image.

4. TEST MODEL

4.1 Lens with Feed Antenna

We tested the lens with the feed antenna to evaluate the half power beamwidth (HPBW) and FOV of the lens and the feed antenna. The signal was generated through a standard gain horn antenna using a VCO and a source locking counter. The test configuration is shown in Figure 7. As the focal point goes to the outermost, the beamwidth is broadened. The power at the outermost focal point was smaller than that at the center focal point by -9 dB. Since the standard horn antenna was directive, the power difference between the center and the outermost was larger than the expected value.

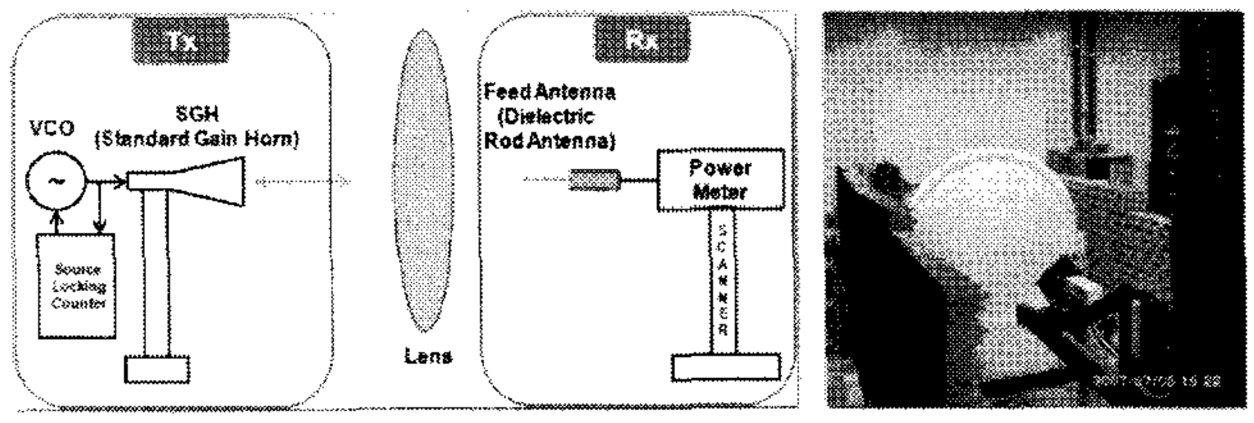

Figure 7. Test Configuration.

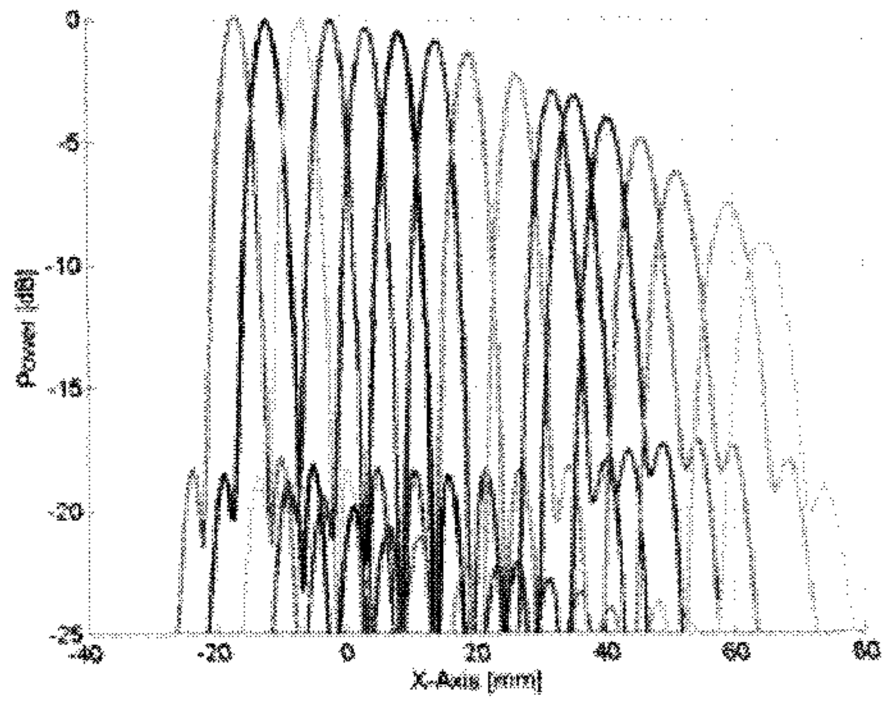

Figure 8. Beam Patterns on Focal Plane of Feed Antenna with Lens.

4.2 RF Receiver with Feed Antenna

The gain of the RF receiver equipped with the feed antenna was measured to evaluate their bandwidth and to check whether they were well-matched. They were matched and their gain and bandwidth shown in Figure 10 were similar to those of RF amplifier shown in Figure5.

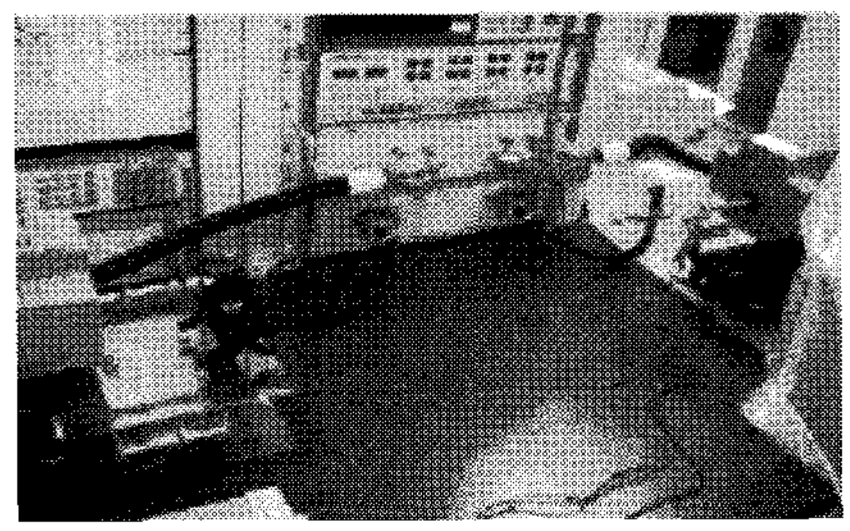

Figure 9. Test Configuration.

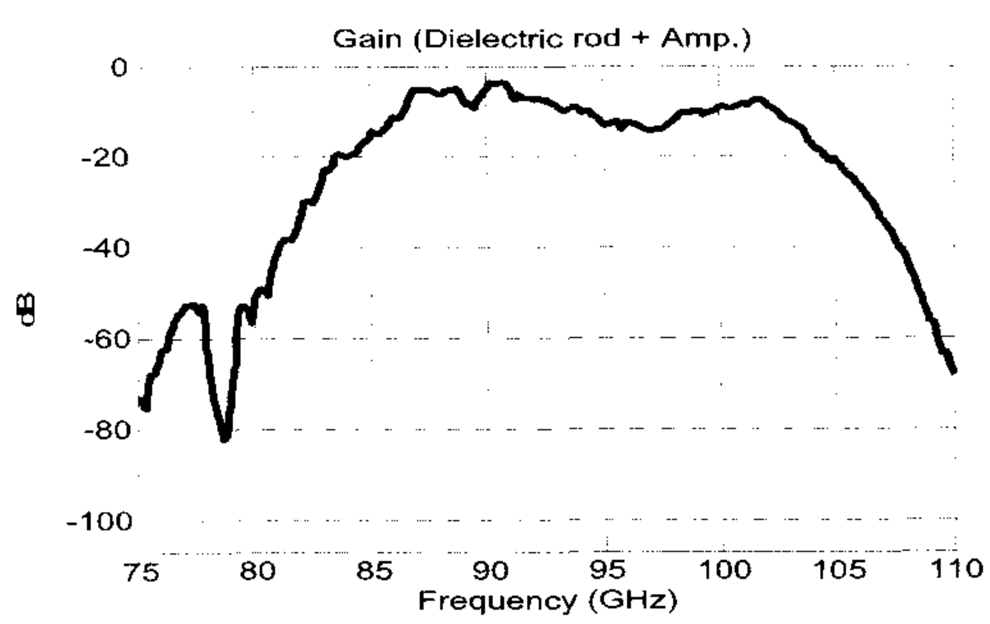

Figure 10. Gain of Feed Antenna and RF Amp.

5. CONCLUSION

The development of MIRAE was started in the end of 2006. Recently, the some components and module for MIRAE was developed and their test was finished. The test results of lens, feed antenna, RF amplifier were satisfied with the requirements.

The future plans are:

- Test of manufactured detector's return loss
- Development of single channel radiometer

6. REFERENCES

References from Books:

F. Ulaby, R.K. Moore, and A.K. Fung, 1986. *Microwave Remote Sensing. Active and Passive, Vol I,* Artech. House.

N. Skou, and D. M. Le Vine, 2006. *Microwave Radiometer Systems: Design and Analysis, Second Edition.* Artech House Publishers.

References from Other Literature:

D. G. Gleed, R. Appleby, N. A. Salmon, S. Price, G. N. Sinclair, R. N. Anderton, J. R. Borrill, M. R. M. Wasley, and A. H. Lettington, 1997. Operational issues for passive millimeter-wave imaging systems, Proc. SPIE Int. Soc. Opt. Eng. 3064, 23

R. N. Anderton, R. Appleby, and P. R. Coward, 2005. Sampling passive millimeter wave imagery. Proc. SPIE Int. Soc. Opt. Eng. vol. 5989.

R, Kuroda, G. S. Dow, Y. Guo, R. Johnson, M. Biedenbender, A. Marashi, L. Yujiri, and M. Shoucri, 1997. Direct detection MMIC FPAs for MMW imaging. Proc. of SPIE, Passive Millimeter-Wave Imaging Technolo;gy, vol. 3064, pp 90~97.

7. ACKNOWLEDGEMENTS

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