Development of a Module for the 23 GHz-band Image Wireless Transfer System

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ABSTRACT In recent large-scale disasters occurring frequently, situations such as the wired broadcasting and communications shutting down over a long period of time happen and therefore the redundancy with wireless is required. We have developed a module for the 23 GHz-band image wireless transfer system with the aim to secure transmission lines for emergency rehabilitation and to the display of problem area of broadcasting while the trunk transmission line facilities of the cable television are damaged. Here, we are introducing the conceptual and basic performances of the module we developed.

1. INTRODUCTION

With the Great East Japan Earthquake, many infrastructures for information and telecommunications were damaged and it became difficult to use the public services. On the cable television facilities, the trunk transmission lines were shut down and took more than one month to recover.

The 23 GHz-band image wireless transfer system is the system that converts VHF/UHF-band image signal into 23 GHz-band wireless frequency and transmits image. It has been used as a fixed station for the solution of the display of problem area of broadcasting and, in response to the Great East Japan Earthquake, the legal systems are revised to make it available to use as a portable station for use as a redundant system of cable television.

In this report, we introduce the concept of the development of the 23 GHz-band image wireless transfer system with the aim of operating it as a portable station.

2. CONCEPT OF THE DEVELOPMENT

2.1. Purpose of the Development

The 23 GHz-band image wireless transfer system is in compliance with the standard of Quasi-Millimeter-Wave-Band Wireless Access System JCTEA STD-023[1]. Its main specification is shown in Table 1. In a traditional system for fixed station, each element block consists of discrete components and it becomes a subject of interference when downsizing it to a portable station. Therefore, we worked to make each element block a high integrated module for downsizing of the system.

Table 1 Specification of the 23 GHz-band wireless transfer system.

Item	Classification	Specification	Unit
Radio Frequency	Fixed System	23.2-23.6	GHz
	General-Purpose Portable System	23.28-23.52	
	Portable System for Isolated Areas	23.2-23.6	
Antenna Power	Fixed System	< 1.0	W
	General-Purpose Portable System	< 0.5	
	Portable System for Isolated Areas	< 0.005	
Frequency Deviation		< 300	ppm
Receiver Noise Figure		< 8.0	dB
Phase Noise (TX / RX)		< 0.5	deg
Transmission Method		Unidirectional Communication	—
Modulation Method		FDM-SSB	—
Operating Temperature		−20 - +40	℃

2.2. Specification of the Module

The specification of the transmitter module and of the receiver module, which performances are defined from the system specification, are shown in Table 2 and Table 3 respectively. To make both high-frequency performance and high-integration compatible available at the same time, we apply a multilayered technique of high-frequency wave substrate and use reflow Monolithic Microwave Integrated Circuit (MMIC) component represented by Quad For Non-Lead (QFN) package.

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Table 2 Specification of the transmitter module.

Item	Specification	Unit
Input Frequency (VHF)	90-470	MHz
Input Frequency (UHF)	336-710	MHz
RF Output Signal Frequency	23.2-23.6	GHz
Conversion Gain	42.0±1.0	dB
In-band Frequency Deviation	≦2.0	dB
P1dB	≧+23.0	dBm
Gain Control Range	≧27.0	dB
IM3@Pout+2.7 dBm/tone	≧60	dBc
LO Leak	≦−40	dBm
Spurious (1st LO+2nd LO)	≦−33	dBm

Table 3 Specification of the receiver module.

Item	Specification	Unit
RF Input Signal Level	−82-−27	dBm
Noise Figure	≦8.0	dB
Conversion Gain	≧14.0	dB
In-band Frequency Deviation	≦2.0	dB
Gain Control Range	≧27.0	dB
IM3@VHF/UHF Pout-21.7 dBm/tone	≦−54.0	dBc

3. MODULE DEVELOPMENT

For downsizing of the portable station, the main function unit requires downsizing and reduction of the power consumption. We refer to the frequency layout, the downsizing technique and the frequency stabilization technology which are important for that purpose.

3.1 The Frequency Layout

The spurious emission intensity of the 23 GHz-band image wireless transfer system is specified, as the fixed station/portable system for the isolated area, in the spectrum mask of Figure 1.

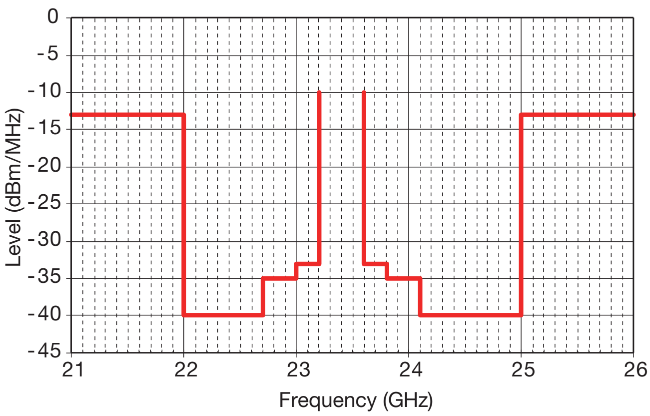

Figure 1 Spectrum mask for the fixed system/portable system for the isolated area.

Table 4 Spurious specification of the fixed system/portable system for the isolated area.

Frequency Range	Spurious Emission
22.0 GHz-22.7 GHz	-40 dBm/MHz or less
22.7 GHz-23.0 GHz	-35 dBm/MHz or less
23.0 GHz-23.2 GHz	-33 dBm/MHz or less
23.6 GHz-23.8 GHz	-33 dBm/MHz or less
23.8 GHz-24.1 GHz	-35 dBm/MHz or less
24.1 GHz-25.0 GHz	-40 dBm/MHz or less

Generally, employing the single conversion system which converts VHF/UHF-band image signal into the 23 GHz-band at once, a spurious signal such as local oscillation signal or image signal is close to the transmission band as shown in Figure 2. For an attenuation of a spurious signal, the use of a waveguide filter with steep cut-off characteristic is popular and is one of the factors of increase in system size.

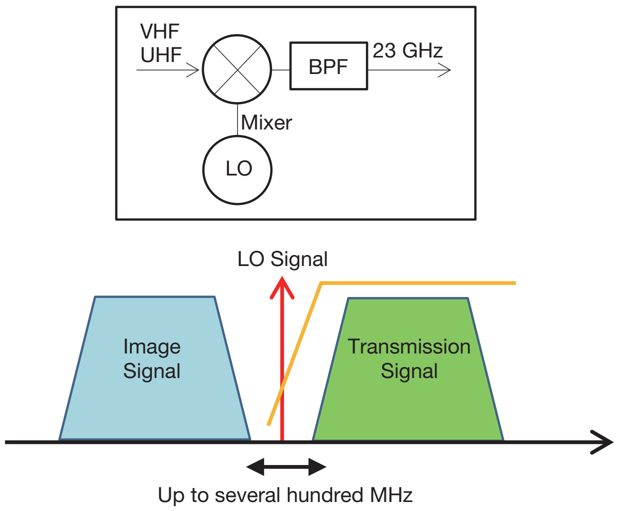

Figure 2 Single conversion system.

Figure 3 shows the block diagram of the transmitter module with the double conversion system employed in this development. VHF/UHF-band image signal is converted to the 2 GHz-band of IF frequency by two mixers, and then the IF frequency is converted to the 23 GHz-band wireless frequency.

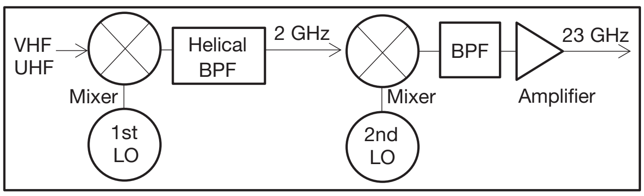

Figure 3 Block diagram of the transmitter module.

By allocating the 1st LO frequency near 2 GHz and the 2nd LO frequency near 21 GHz as the local oscillations of the mixers and by keeping transmitting band and spurious signal far away from each other, it is possible to ease the required specification for the filter and to achieve the downsizing of the system.

3.2 The Filter Development

VHF/UHF to IF frequency layout of mixer output (IF frequency) in the double conversion system is shown in Figure 4 and frequency layout for IF band to RF band of mixer output (RF frequency) in the double conversion system is shown in Figure 5.

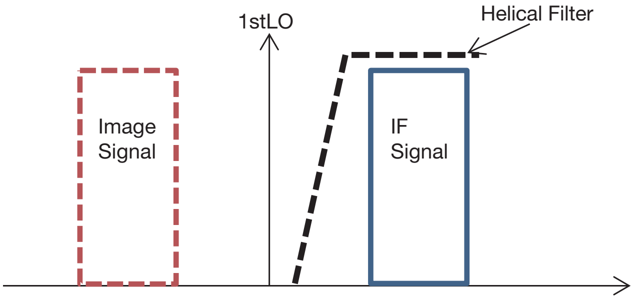

Figure 4 VHF/UHF to IF frequency layout.

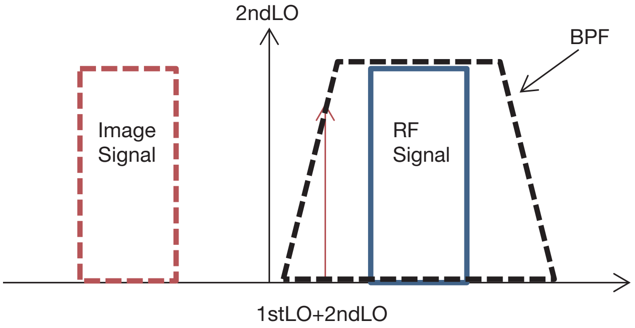

Figure 5 Frequency layout for IF band to RF band.

For the IF band, we have developed a helical resonance type filter consisting of a triple solid resonance circuits which is superior to the cut-off characteristic (high Q value) for the1st LO attenuation. Its configuration and structure are shown in Figure 6, its specification is shown in Table 5 and its evaluation result is shown in Figure 7. The helical filter achieves the characteristic that the 1st LO can be self attenuated by approximately 50 dB.

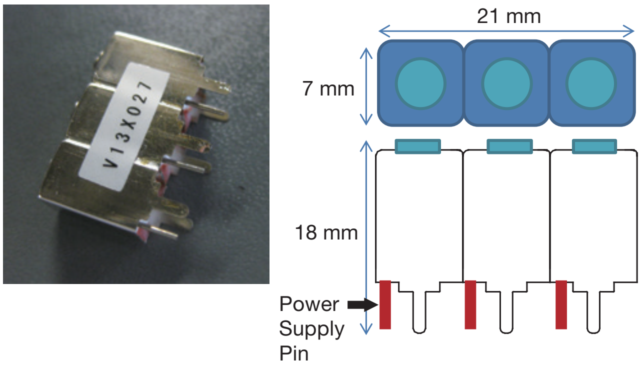

Figure 6 Helical filter configuration and structure.

Table 5 Specification of the helical filter.

Passband	1965-2345	MHz
Insertion Loss	2.0-4.0	dB
Attenuation Pole Frequency	1785-1875	MHz
Attenuation Amount	≧50.0	dB

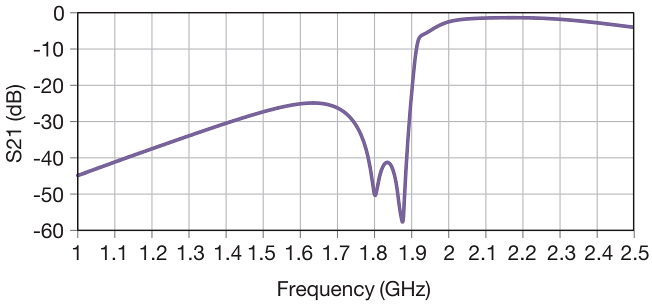

Figure 7 Evaluation result of the helical filter.

The BPF installed in the 23 GHz-band circuit attenuates the 2nd LO or the intermodulation component and consists of a dielectric waveguide filter. The component size is as small as 15.7 mm x 4.1 mm x 1.9 mm and a reflow mounting is available. Each configuration, pass characteristic and specification of the developed BPF are shown in Figure 8, Figure 9 and Table 6, respectively. With the pass characteristics (S21), the filter which can attenuate the 2nd LO by more than 40 dB is achieved.

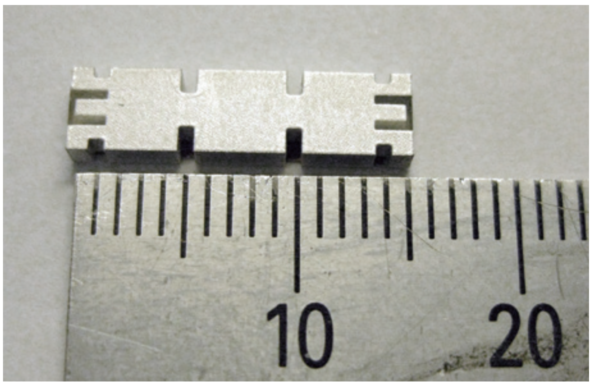

Figure 8 BPF configuration.

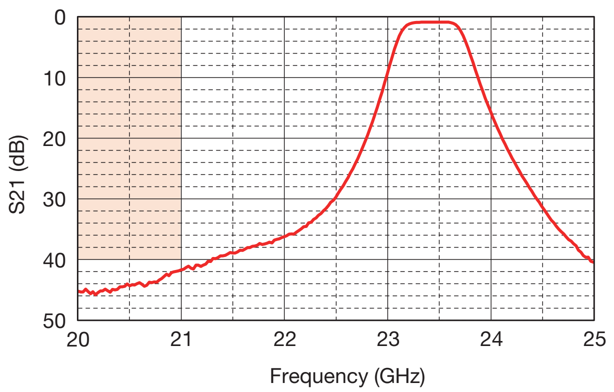

Figure 9 BPF pass characteristic.

Table 6 Specification of BPF.

Passband	23.2 ～ 23.6	GHz
Insertion Loss	≦2.0	dB
Attenuation Amount (23.4 ± 1.8 GHz)	≧40	dB

3.3 The Downsizing Technique

The modules use many MMICs (GaAs process, short gate length of less than 0.15 mm) sealed in QFN packages for both the transmitter and the receiver. QFN package has a quite narrow terminal distance of 0.2-0.3 mm and is easy to oscillate because of its high gain, therefore, it is required that the pattern design ensures enough isolation characteristic to the gain.

Figure 10 shows an electromagnetic simulation result of an LNA's (Low Noise Amplifier: 4 mm x 4 mm of component package configuration) footprint by itself. Even though LNA has more than 26 dB of gain, it is confirmed that an isolation characteristic is approximately 40 dB within the transmission band with the footprint including through holes.

3.4 The Frequency Stabilization Technique

To match the image signal frequencies of the transmitter and the receiver on the 23 GHz image transfer system, it is necessary to uniform each local oscillating frequency, however, the oscillating frequency shifts happen according to the temperature or the individual differences. Therefore, on a general wireless system, the system is designed to allow some degree of frequency deviation. However, this system cannot allow frequency deviation of wireless unit for use as a redundant system of cable television which does not assume frequency shifts. This system achieves complete frequency control by adding of a pilot signal on the transmitter side, by extracting the pilot signal through feedback on the receiver side and by synchronizing the VCXO. Figure 11 shows block diagrams of the pilot synchronization.

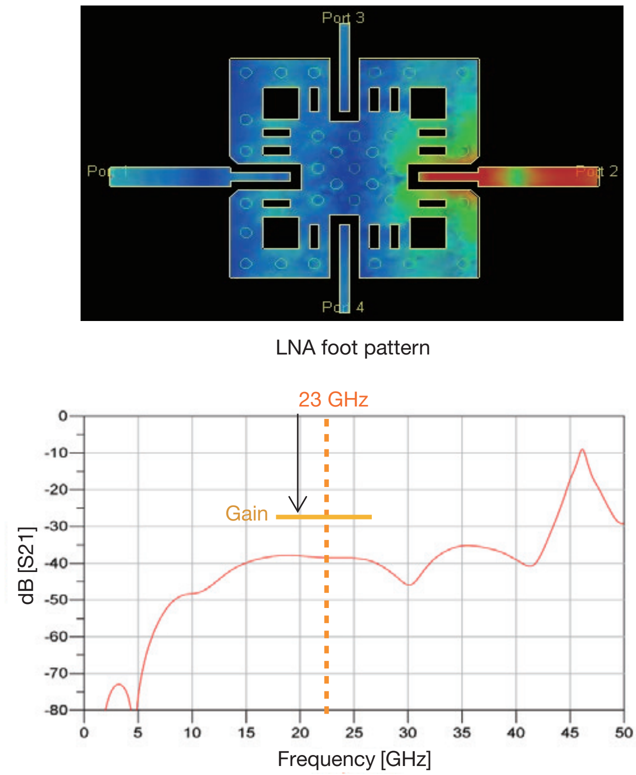

Figure 10 EM simulation model and result.

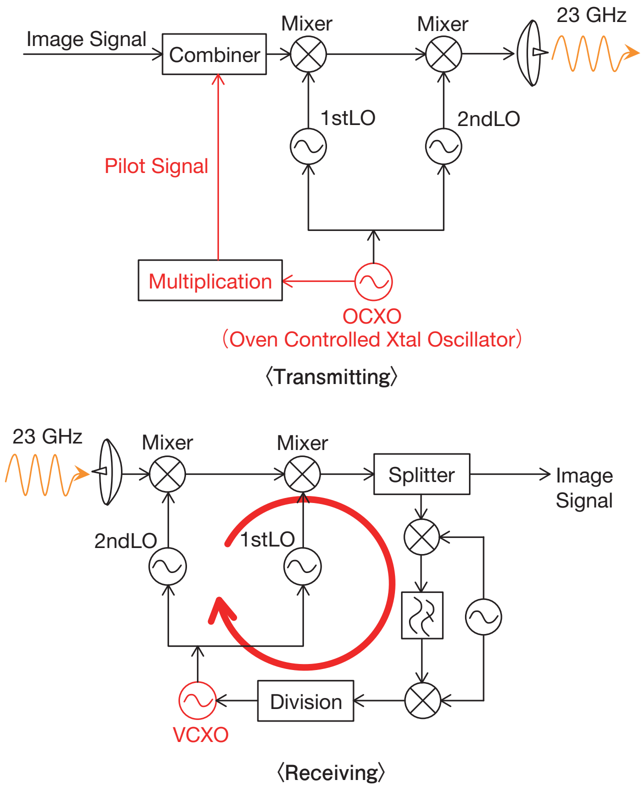

Figure 11 Block diagrams of pilot synchronizing.

4. The MODULE DEVELOPMENT

The evaluation result of the developed transmitter module is shown in Figure 12. It satisfies the specification with the conversion of approximately 42 dB and the frequency deviation of less than 1.5 dB. Figure 13 shows the evaluation result of transmitting spurious. By the double conversion system, the 2nd LO has enough attenuation amount and become less than the noise floor of measurement system. The spurious of 1st LO + 2nd LO is also satisfying the standard of less than -33 dBm in the range of 23.0 – 23.2 GHz.

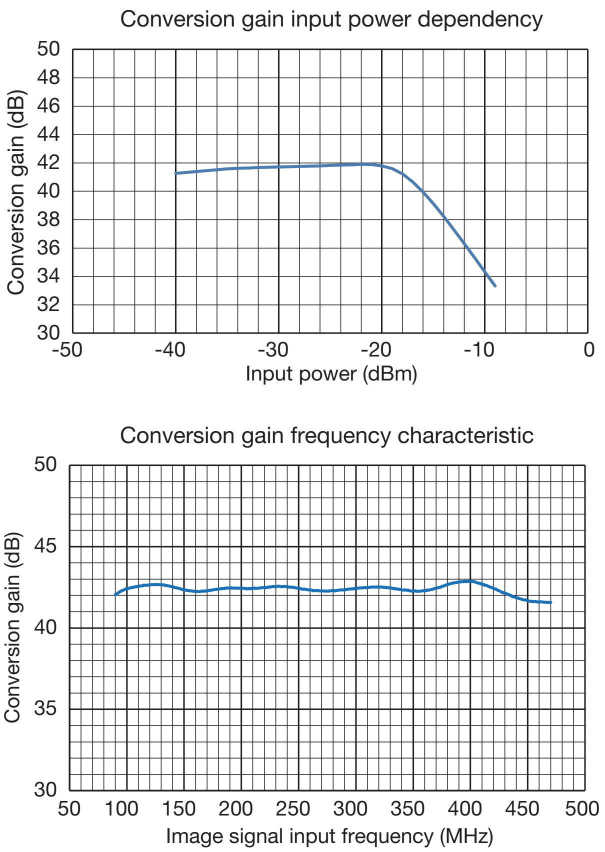

Figure 12 Conversion gain of the transmitter module.

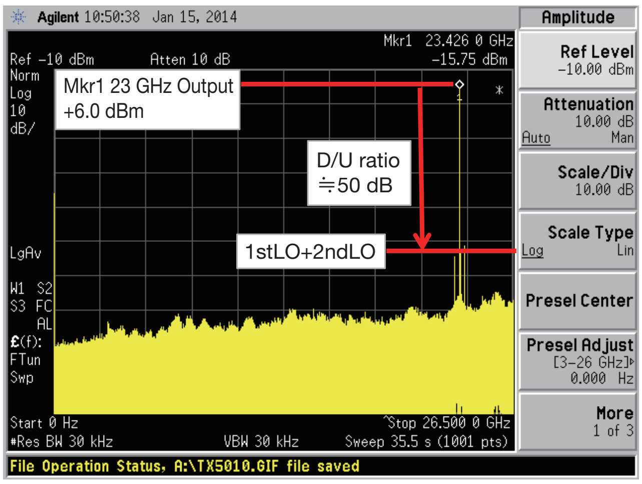

Figure 13 Evaluation result of TX spurious.

Table 7 shows the evaluation result of the transmitter and the receiver modules. In CTEA STD-023, the preferable phase noise performance is specified as less than or equal to 0.5 deg rms for the total value of the transmitter/ receiver FDM-SSB carrier wave (integration range of 100 MHz – 1 MHz).

Table 7 Evaluation result of the modules.

Transmitter

Item	Specification	Evaluation Result	Unit
Conversion Gain	≧42.0	≧42.0	dB
In-band Frequency Deviation	≦2.0	≦1.5	dB
P1dB	≧+24.0	≧+24.0	dBm
IM3@Pout+2.7 dBm/ tone	≧60.0	≧61.0	dBc
1st LO + 2nd LO	≦−33 dBm/ MHz	≦−40.0	dBm
1st LO + 2 x Image Signal + 2nd LO	≦−33 dBm/ MHz	≦−40.0	dBm

Receiver

Item	Specification	Evaluation Result	Unit
RF Input Signal Level	−82 - −27	—	dBm
Noise Figure	≦8.0	≦7.0	dB
Conversion Gain	≧14.0	≧15.0	dB
In-band Frequency Deviation	≦2.0	≦1.3	dB
Gain Control Range	≧27.0	≧33.0	dB
IM3@VHF/UHF Pout -21.7 dBm/tone	≦−54.0	≦−63.0	dBc

Table 8 shows the phase noise characteristic of the synchronized signal which is restored at the receiver from the pilot signal which is added at the transmitter. With the frequency stabilization technique and the phase noise reduction of each oscillator, the phase noise characteristic required for the 23 GHz image wireless transfer system is satisfied.

Table 8 Phase noise characteristic.

Spot. Frequency	Specification	Unit	TX / RX Opposing
100 Hz	−75.0	dBc/Hz	−79.12
1 kHz	−85.0	dBc/Hz	−86.30
10 kHz	−95.0	dBc/Hz	−95.50
100 kHz	−105.0	dBc/Hz	−113.12
1 MHz	−110.0	dBc/Hz	−122.89
	0.5	deg rms	0.346

The configuration of the prototype transmitter module is shown in Figure 14. The prototype module is achieved downsizing by less than 40% in volume ratio, with its size of 200 mm x 200 mm x 30 mm, toward a traditional module size of 150 mm x 350 mm x 80 mm.

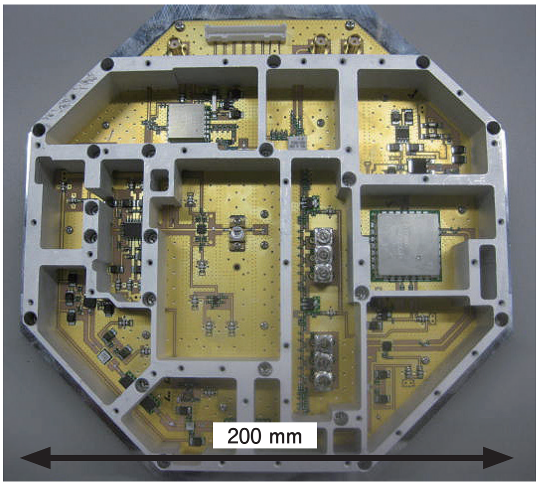

Figure 14 TX module configuration.

5. CONCLUSION

We have developed the module which convert VHF/UHF-band image wireless transfer signal to 23 GHz-band. The 23 GHz-band image wireless transfer system mounting this module is assumed for the applications not only as a countermeasure of wireless redundant but also as a resolution of the display of problem area of broadcasting. It is anticipated the growing needs of interaction or capacity growth accordingly as expanding the use of the image transfer system progresses in the future. We will focus to further increase in performance, downsize and reduce cost.

ACKNOWLEDGEMENTS

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REFERENCES

1) JCTEA STD-023, "23 GHz Band Wireless Access System: An Access System using an 23 GHz Band".
2) ARIB STD-T58, "Fixed Wireless Access System Using Quasi-Millimeter-Wave-And Millimeter-Wave-Band Frequencies Point-To-Point System".
3) The frequency stabilization technique with the pilot synchronization is patented (Patent registration number (in Japan) : 5840283).