Radio Frequency Interference research around the Ishioka Station using the VGOS broadband receiver

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Abstract The Ishioka Station participates in legacy S/X sessions and VGOS Trial sessions using different receiving systems. In order to participate in legacy S/X sessions with VGOS broadband receiving system (i.e. mixed-mode observation), we need to improve the VGOS broadband receiver to receive S-band (2-3 GHz). We investigated the Radio Frequency Interference (RFI) environment around the Ishioka Station and found that LNA in VGOS broadband receiver is saturated by two strong RFI signals below 3 GHz. We plan to design a superconducting filter that suppresses those signals by 30 dB or more and incorporate it into our broadband system.

1. Introduction

Receiver exchange is necessary for observation at the Ishioka Station

The Ishioka Station operated by the Geospatial Information Authority of Japan (GSI) participates in both legacy S/X sessions and VGOS Trial sessions conducted by the International VLBI Service for Geodesy and Astrometry (IVS).
The Ishioka Station employs different receiving system for legacy S/X and VGOS broadband sessions. Therefore, we need to exchange the receiving systems when observation mode is switched. Currently at the Ishioka Station we mainly perform legacy S/X sessions. The number of VGOS Trial sessions is limited because of the difficulty in frequently switching receiving systems (Fig.1).

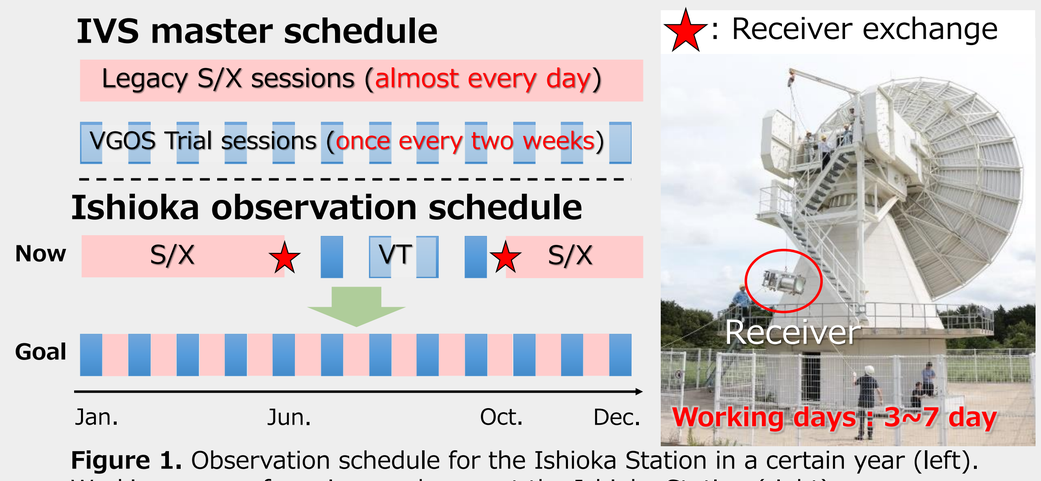


Figure 1. Observation schedule for the Ishioka Station in a certain year (left). Working scene of receiver exchange at the Ishioka Station (right).

For realization of S/X sessions by the broadband system

The current VGOS broadband receiving system loaded with the Ishioka Station can't observe S-band (2-3 GHz) signals. It has a high-pass filter for cutting 3 GHz or below signals because the amplifiers are saturated by strong RFI signals.
In order to observe the S-band with the VGOS broadband receiving system, it is necessary to suppress only strong RFI signals that causes saturation at the amplifier. We investigated the RFI environment around the Ishioka Station and identified strong RFI signals.

2. RFI environment around the Ishioka Station

We investigated the RFI environment around the Ishioka Station to find out the overall trend and characteristic of RFI.
As a preliminary investigation of the RFI environment, it was conducted with a Dual-Ridge Horn Antenna (Fig.2) toward 4 directions (north, south, east and west) because the Ishioka Station didn't have enough time for the investigation using the VGOS broadband receiving system.

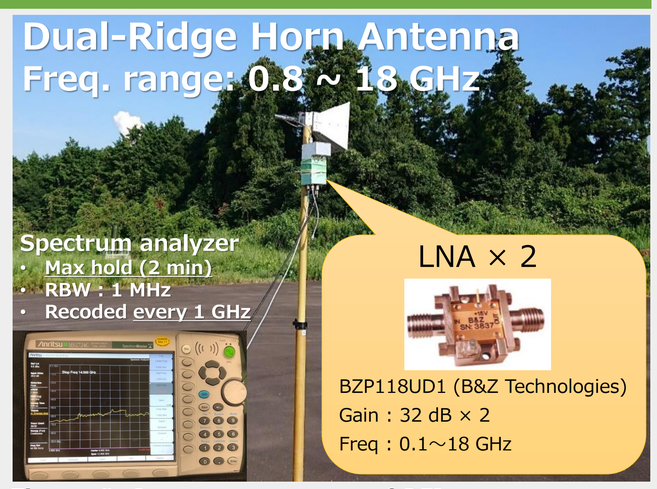


Figure 2. Investigating scene of RFI environment at the Isioka Station using broadband observing system owned by the NICT.

The strongest RFI signal (radar) at 2.840 GHz received from east direction.

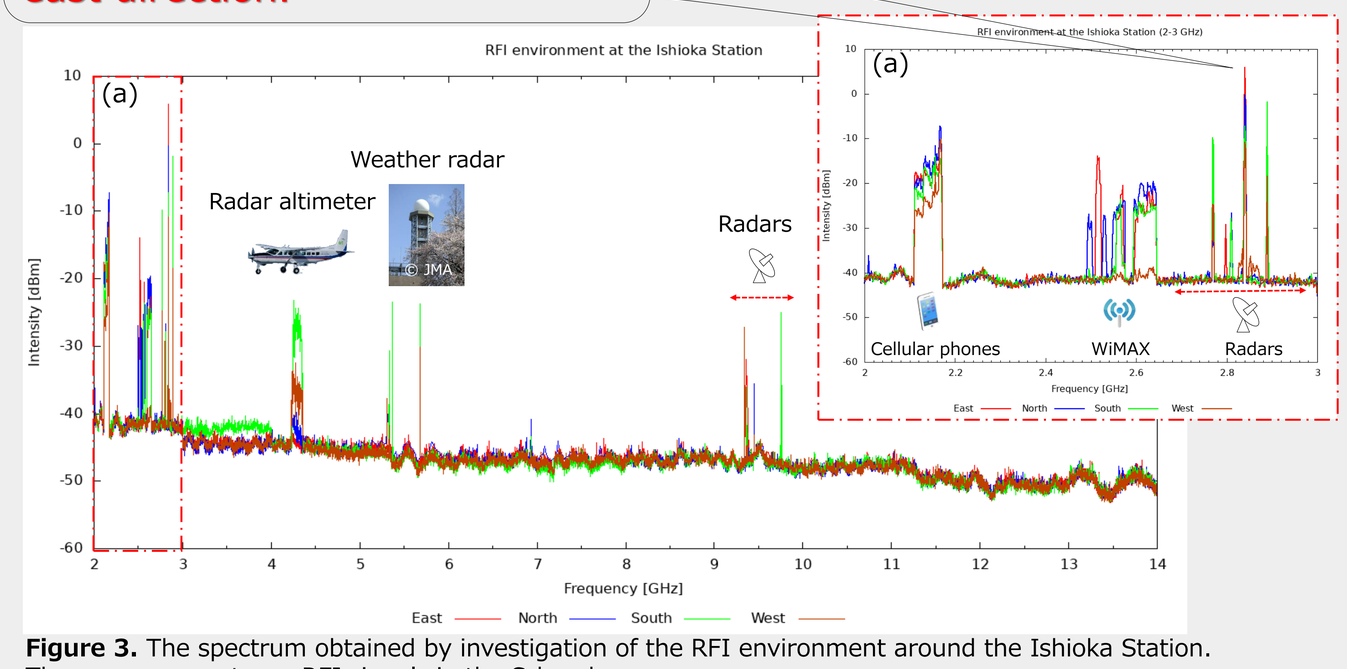
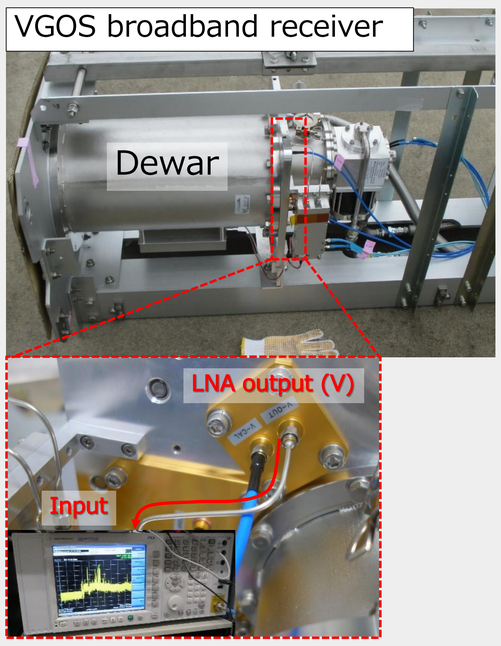


Figure 3. The spectrum obtained by investigation of the RFI environment around the Ishioka Station. There are many strong RFI signals in the S-band.

3. Identifying strong RFI signals that causes amplifier saturation

Investigation of strong RFI signals using the Ishioka 13m Antenna



In order to identify strong RFI signals that causes amplifier saturation, we made RFI survey with Ishioka 13m Antenna toward east direction, where the strong RFI was received in the RFI survey described in section 2.
We connected a spectrum analyzer as shown in Fig.4 and recorded maximum receiving power in 9 elevation directions from 90 (zenith) to 5 degree.
Fig.5 shows the RFI spectrum obtained by the investigation.

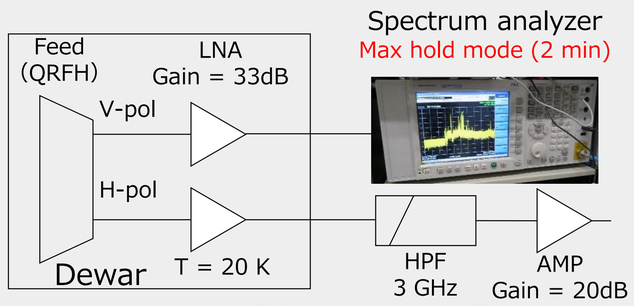


Figure 4. The VGOS broadband receiver and measurement point of the spectrum analyzer.

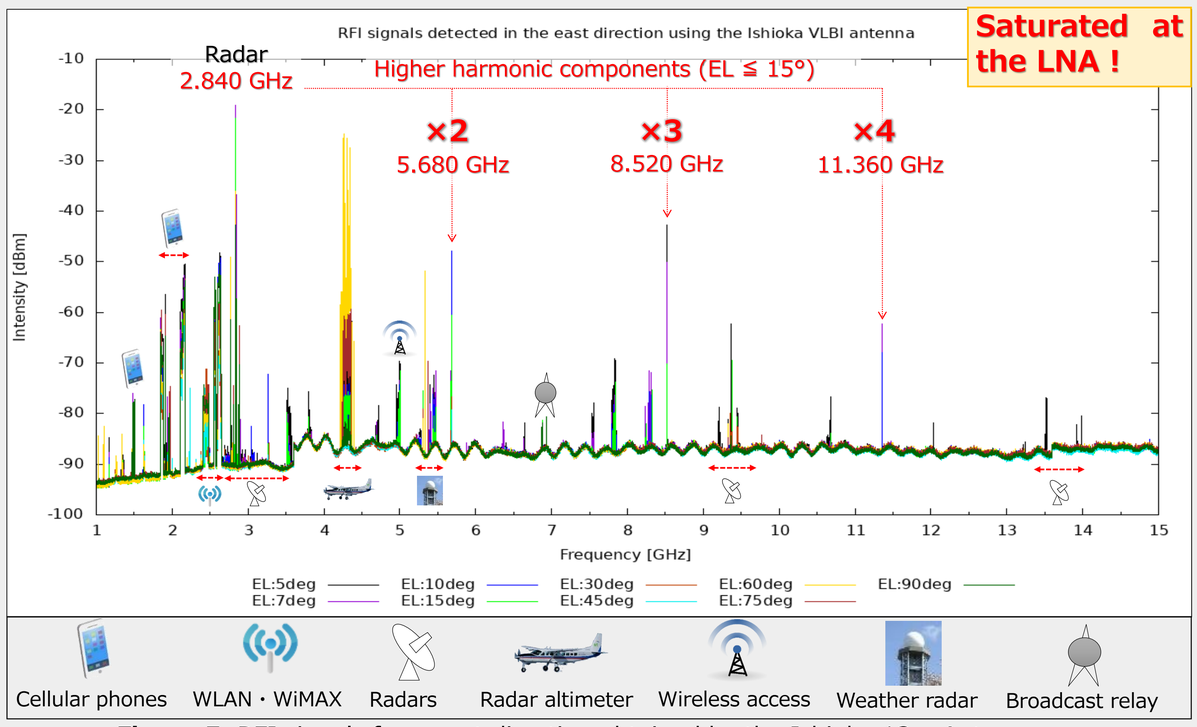
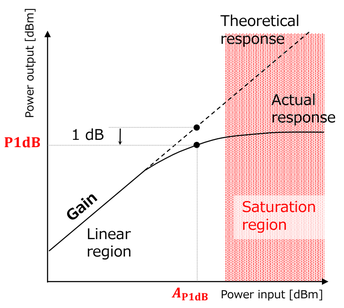


Figure 5. RFI signals from east direction obtained by the Ishioka 13m Antenna.

Estimating excess level of the RFI signals using the P1dB

What is P1dB?

- P1dB is the output power level of which the difference from the theoretical response is equal to 1 dB.
- One of the indicators of amplifier saturation.



LNA status at the Ishioka

Gain	P1dB	A_{P1dB}
33 dB	-10 dBm	-42 dBm

Estimating excess and suppress level

$$\left(\frac{A}{A_{\mathrm{P1dB}}}\right)^2 = \frac{4\sqrt{\frac{P_3}{P_1}}}{0.145\left(1+3\sqrt{\frac{P_3}{P_1}}\right)}$$

$$P_{\mathrm{ex}} = 10\log\left(\frac{A}{A_{\mathrm{P1dB}}}\right)^2$$

P_1 : Power of the fundamental harmonic
P_3 : Power of the third harmonic
A : Input power of the RFI signal

RFI name	Excess level P_{ex}	Suppress level before the LNA
Radar (2.840 GHz)	+2.16 dB (-39.86 dBm)	**> 26 dB** (Consider 4 AMPs)
Phone※ (2.168 GHz)	+1.72 dB (-40.28 dBm)	**> 25 dB** (Consider 4 AMPs)

※The signal is saturated when the Ishioka 13m antenna is pointed at the mobile base station.

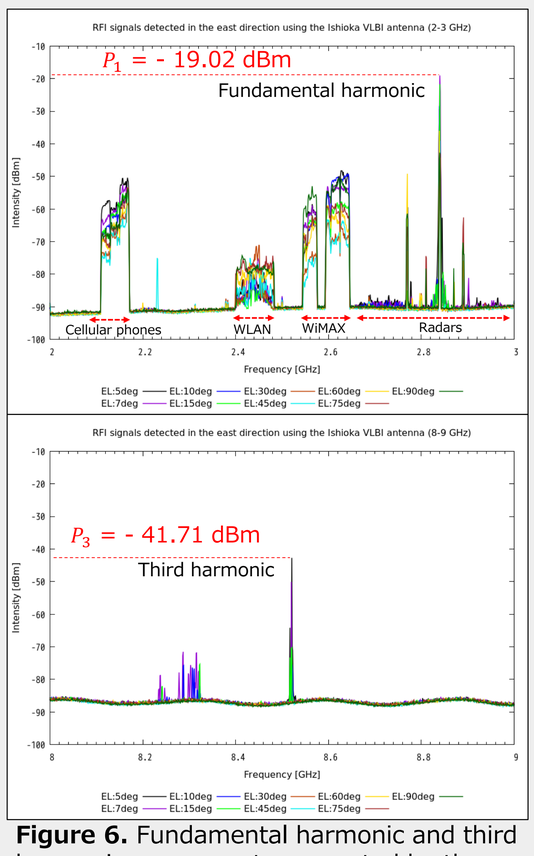


Figure 6. Fundamental harmonic and third harmonic components generated by the radar at 2.840 GHz.

Consideration of superconducting filter to prevent signal saturation

We plan to place the superconducting filter between Feed and LNA to suppress strong RFI signals. We are designing the filter that suppress three RFI signals (Cellular phone, WLAN・WiMAX and 2.840 GHz Radar) sharply by 30 dB or more.

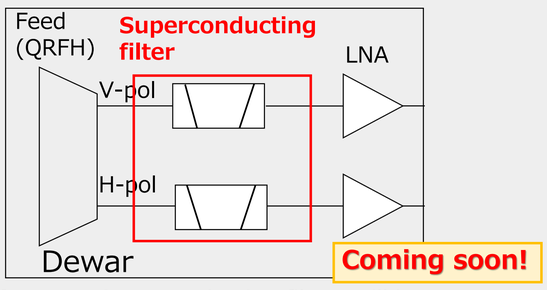


Figure 7. Superconducting filters will be placed between Feed and the LNA.

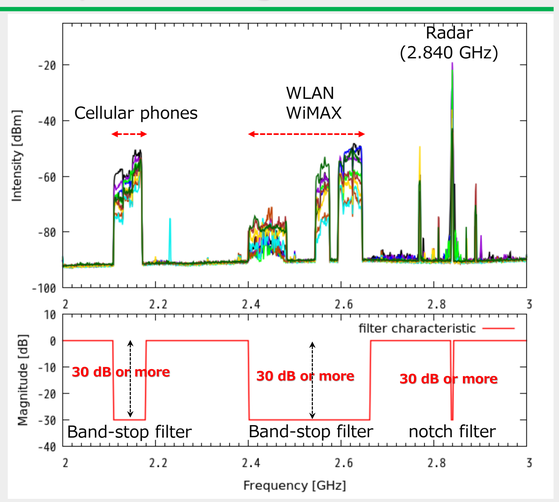


Figure 8. RFI signals from 2 to 3 GHz detected from east direction using the Ishioka 13m antenna (upper panel). The characteristic of the superconducting filter (lower panel).

Acknowledgement
We would like to thank Dr. Sekido for lending the equipment and giving a lot of advice as part of joint research.