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Wideband RF Interference Reduction Module

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Abstract

Interference always exists between wireless communication systems used in the same frequency band or adjacent frequency bands. In order to deploy a new wireless communication system such as a 5G system, a new frequency band must be allocated to the system. For this purpose, after analyzing interference between the existing system and the new system, a method of setting a frequency guard band or a minimum separation distance has been used as a passive method to limit the interference effect. This paper presents a wideband RF IRM(Interference Reduction Module) that can actively reduce the influence of interference between wireless communication systems. The wideband RF IRM can reduce the interference effects of 5G signals on satellite signals. The principle and structure of the wideband RF IRM are presented. The wideband RF IRM can suppress approximately 20dB of interference signal in 100MHz bandwidth when only interference signal exists. It also shows that when a 5G interference signal of -45dBm/100MHz and a satellite signal of -55dBm/40MHz exist simultaneously at a center frequency of 3.83GHz, about 15dB of 5G interference signal can be reduced in the frequency range covered by the satellite signal. The experimental results demonstrate that the wideband RF IRM can actively reduce the 5G interference signal on the satellite signal and can be used for the purpose of reducing the interference effect in a similar environment.

Key words: Interference, Interference Cancellation, Wideband, Transceiver.

1. INTRODUCTION

Interference degrades the performance of wireless communication systems. Unfortunately, there is always interference between wireless communication systems used in the same frequency band or in adjacent frequency bands. In order to deploy a new wireless communication system such as a 5G system, a new frequency band must be allocated to the new system after analyzing interference between the existing system and the system to be newly built. In general, a method of reducing interference between wireless communication systems includes a method of providing a frequency guard band or limiting a minimum separating distance between wireless communication systems[1]. Such a passive method has disadvantages in terms of the frequency utilization efficiency and the ease of use.

Full-duplex communication systems, which have been studied a lot recently, provide a means to overcome such shortcomings[2,3,4,5,6]. In full-duplex communication systems, SIC(self-interference cancellation)

technology is used, and SIC technology is used to cancel the interference signal generated by the wireless transceiver itself. If the interference signal generated by other transmitters or transmitters providing other services can be eliminated or reduced, there are significant advantages in terms of the frequency utilization efficiency and the system implementation margin.

5G wireless systems are developed to meet the rapidly increasing data demand and to provide faster service than the existing mobile communication systems. The millimeter wave frequency bands and the sub-6GHz bands are allocated for 5G wireless systems and the sub-6GHz bands include C band. Since 5G systems used in C band utilize the frequency allocated to the existing fixed-satellite system, 5G signal has an interference on the satellite systems. Many researches have been done on the interference effect of the 5G system on the satellite system. For the coexistence of wireless systems providing different services in the same frequency band, a means of reducing interference is required and a passive method is generally used[7,8]. The interference effect of 5G signals on satellite signals is the example of the interference between systems that provide different services. As a method of reducing interference caused by 5G signals, it is common to set a minimum separation distance or suppress the interference signal with a bandpass filter[7,8,9]. Another approach is to limit the transmit power as a way to avoid the worst case when interference occurs[10]. If interference signals can be reduced without increasing the minimum separation distance or reducing the output power in a situation where interference occurs, there are significant advantages in terms of system implementation and frequency utilization efficiency. This paper describes a wideband RF IRM that can reduce the interference effects of 5G signals on satellite signals.

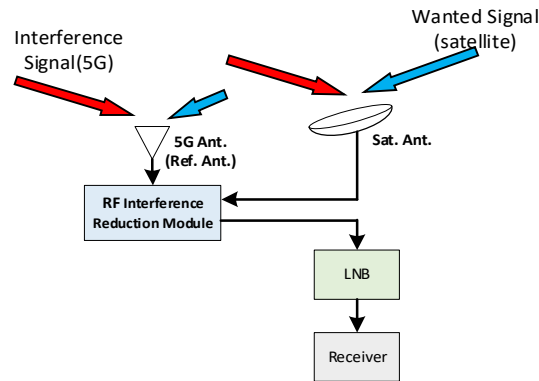## 2. STRUCTURE AND OPERATION OF THE PROPOSED WIDEBAND RF IRM

Figure 1 (a) shows a satellite receiver in an environment where both a wanted signal(satellite signal) and a interference signal(5G signal) are simultaneously received. The antenna used in the satellite receiver is a parabolic antenna having a high gain and can receive not only satellite signals but also 5G signals. Therefore, 5G signals act as an interference signal to the satellite signal. Figure 1 (b) shows the basic structure of RF IRM. In Figure 1 (b), Signal A and Signal B are being applied to Coupler-1 providing the function of the subtraction circuit, and Signal B is being applied to Amplitude & Phase Adjuster. The magnitude and phase of Signal B applied to the Amplitude & Phase Adjuster are adjusted to have the same magnitude and 180 degree phase difference as Signal B. Then, Signal B is cancelled out and only Signal A remains at the output of Coupler-1. Coupler-2 samples a part of the output of Coupler-1 and applies it to Error Detector, and Error Detector detects the magnitude of Signal B as an error and applies the detected error information to Controller. The Controller adjusts Amplitude & Phase Adjuster so that the magnitude of the error detected by Error detector is minimized. Through this process, only Signal A can be outputted to the output of the RF IRM. Figure 1 (c) shows a satellite receiver that can receive satellite signals while reducing 5G interference signals using the RF IRM.
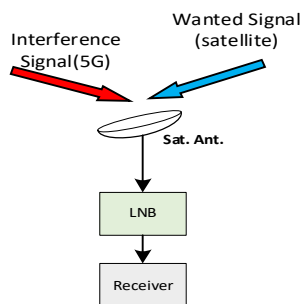
(a) Satellite receiver simultaneously received by 5G and satellite signal
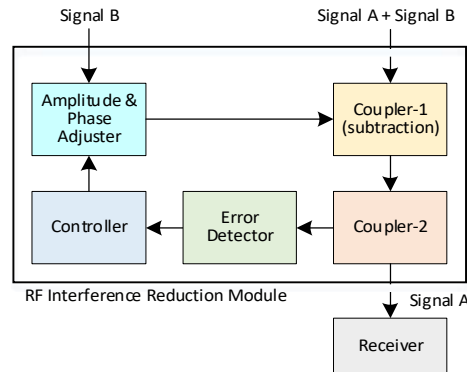
(b) Basic structure of RF IRM

(c) Satellite receiver with RF IRM for reducing 5G interference signal

Figure 1. Structure of RF IRM and satellite receiver using it

3. IMPLEMENTATION AND PERFORMANCE OF THE PROPOSED WIDEBAND RF IRM

The RF IRM that operates as shown in Figure 1 (b) is designed as shown in Figure 2. In Figure 2, the signal received from the reference antenna is applied to Amp & V_Att to adjust the amplitude of the signal. The output of Amp & V_Att passes through Coupler-1 and then is applied to Delay & V_Att. Delay & V_Att is controlled by MCU that generates a control signal according to the amplitude of the error. The output signal of Delay & V_Att is shaped to have the same amplitude and shape as the output signal of Coupler-4, and then is input to Transformer that provides a subtraction function. If two signals applied to Transformer have the same amplitude and shape, they are cancelled out at the output of Transformer. The amount of cancellation is determined according to the amplitude, the 180 degree phase difference, and the degree to which the time delay is maintained. The output signal of the satellite antenna is applied to Delay, and Delay functions to adjust the time delay from the satellite antenna to the transformer and the time delay from the reference antenna to the transformer. The output of Delay is applied to Amp & V_Att to adjust the signal level. The output of Amp & V_Att passes through Coupler-4 and then is applied to the Transformer. In Figure 2, I-Detector detects the amplitude of the input signal, Sat-Detector detects the amplitude of the signal applied from the satellite antenna, DVO-Detector detects the amplitude of the signal that has passed through Delay & V_Att, and E-Detector detects the amplitude of the interference signal at the output of Transformer. The voltage information detected from these detectors is applied to the MCU, and the MCU controls Delay & V_Att using this information and LMS(Least Mean Squares) algorithm[11]. LMS algorithm is used to control the attenuation value of variable attenuators composing Delay & V_Att so that the amplitude of the interference signal detected by E-Detector is minimized.
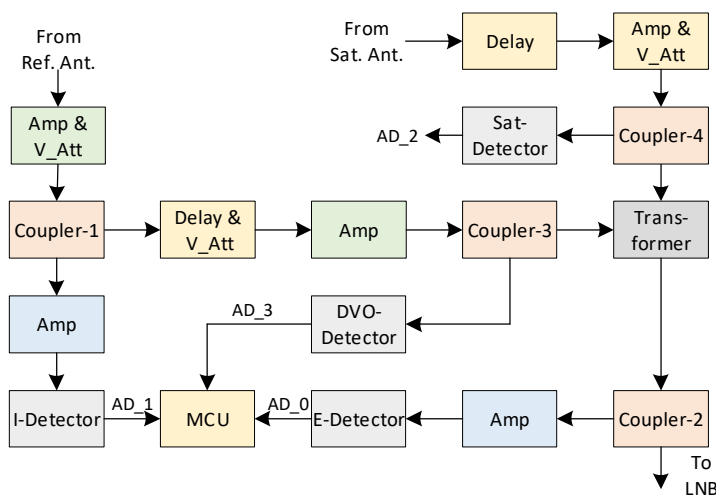
Figure 2. Block diagram of RF IRM

RF IRM of the block diagram in Figure 2 is implemented and the interference reduction performance of the implemented RF IRM is measured. Figure 3 shows the interference reduction performance of RF IRM. If the time delay is not properly matched between the path from the satellite antenna to the subtraction circuit and the path from the reference antenna to the subtraction circuit, the interference reduction characteristics are excellent in a narrow band. But the interference reduction performance cannot be maintained over a wide frequency band. Figure 3 (a) shows the narrowband interference reduction characteristics when a 5G interference signal with a 100 MHz bandwidth exists at a center frequency of 3.83 GHz. In this case, it can be seen that the null of the interference reduction characteristic exists at about 3.81 GHz. If the time delay is properly adjusted between the path from the satellite antenna to the subtraction circuit and the path from the reference antenna to the subtraction circuit under the same conditions, the interference reduction characteristics of RF IRM are shown in Figure 3 (b). Figure 3(b) shows that the interference reduction characteristic of RF IRM is about 20dB in the entire 100MHz band when the time delay is properly adjusted.
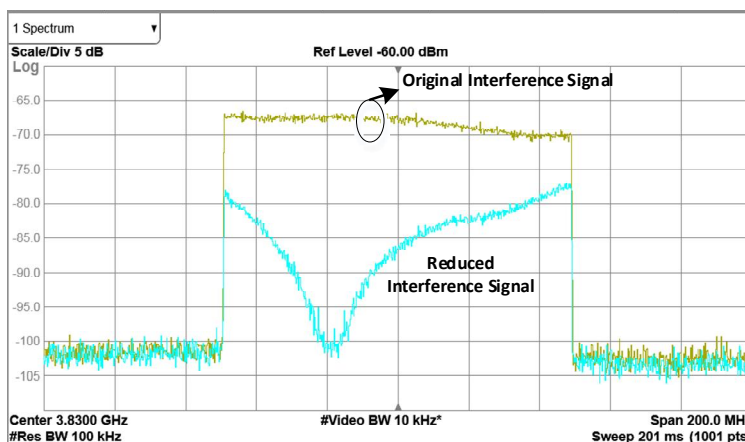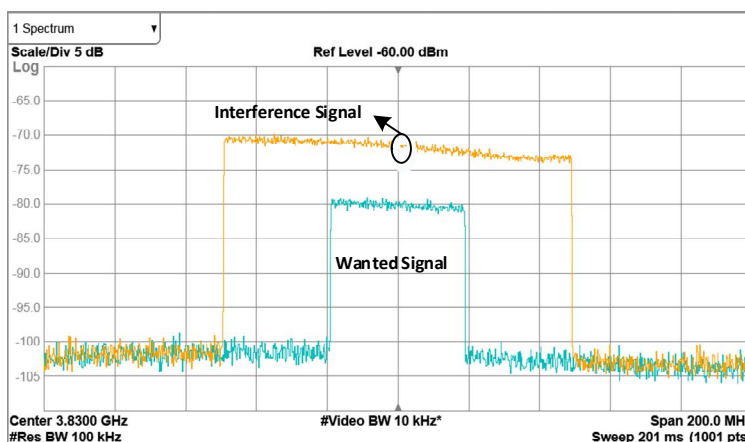

(a) Spectrum of Interference signal before and after operation of RF IRM without adjusting a delay mismatch
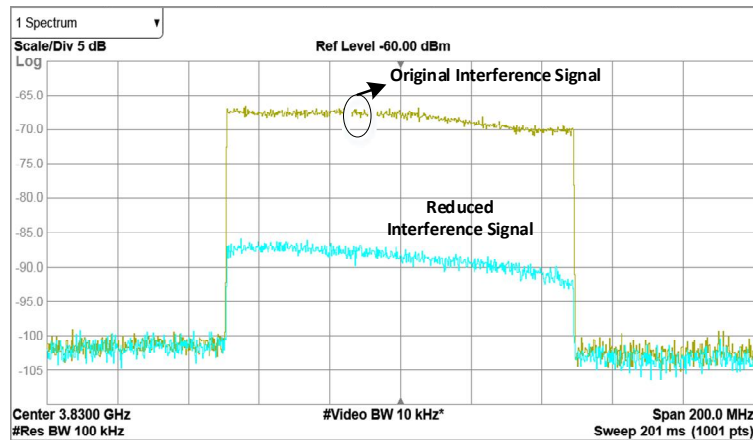
(b) Spectrum of Interference signal before and after operation of RF IRM with adjusting a delay mismatch

Figure 3. Interference reduction performance of the wideband RF IRM(measured at the output of RF IRM)

Figure 4 shows the interference reduction characteristics of RF IRM when a 5G interference signal with 100MHz bandwidth and a satellite signal with 40MHz bandwidth exist at the same time. Figure 4 (a) shows the frequency spectrum for each of the 5G interference signal and the satellite signal applied to RF IRM, and this spectrum is measured at the output terminal of RF IRM. In Figure 4(a), the power of the interference signal is -45dBm and the power of the satellite signal is -55dBm. The spectrum in the upper part of Figure 4(b) shows that the satellite signal is buried in the 5G interference signal and cannot be distinguished well because the power of the 5G interference signal is greater than that of the satellite signal. If you look closely at the spectrum in the upper part of Figure 4(b), you can see that it is slightly raised from the center frequency of the interference signal by the satellite signal. Operating RF IRM in this situation reduces the 5G interference signal. Because the 5G interference signal is reduced, the satellite signal that was not seen by the large interference signal appears. The lower spectrum of Figure 4(b) shows that RF IRM can reduce the interference signal even when the 5G interference signal and the satellite signal are present at the same time. In Figure 4 (b), the interference reduction characteristic does not have the same interference reduction characteristic as in Figure 3. The reason is that when a satellite signal is present, the power cannot be detected below the power of the satellite signal. The lower spectrum of Figure 4 (c) is when the satellite signal is turned off, and this spectrum shows the spectrum of the 5G interference signal reduced through RF IRM. Comparing Figure 4(b) with Figure 4(c) shows that even when the interference signal is 10dB larger than the satellite signal, the interference can be reduced by about 15dB in the 40MHz bandwidth. The picture of the implemented wideband RF IRM is shown in Figure 5.

(a) Spectrum of 5G interference signal and satellite signal
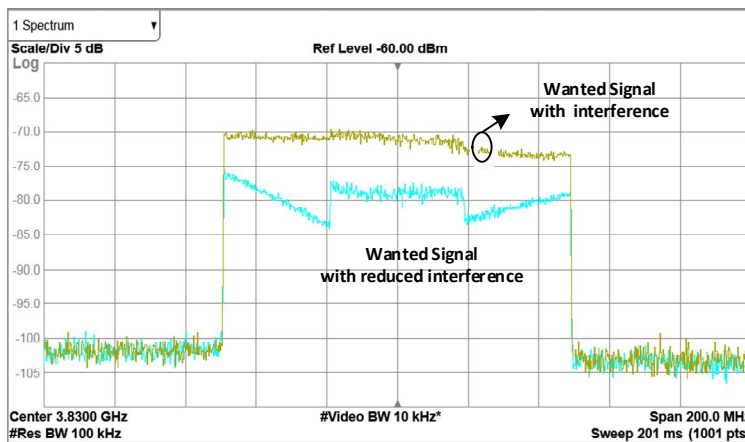
(b) Output spectrum before and after RF IRM operation
(upper trace: before RF IRM operation, lower trace: after RF IRM operation)
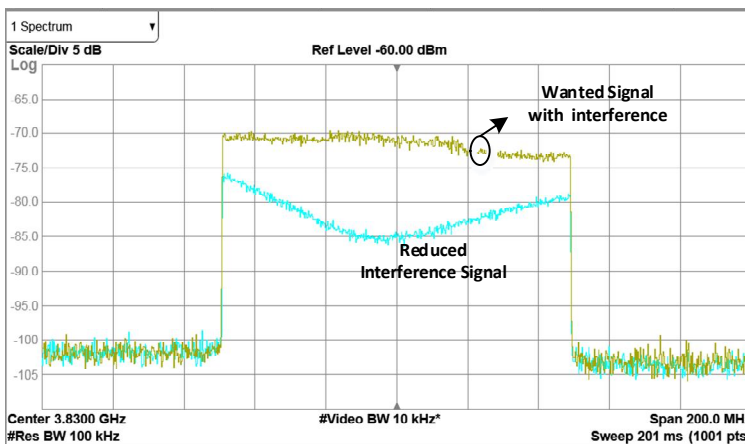
(c) Output spectrum before RF IRM operation and Output spectrum after RF IRM operation with turning off the satellite signal

Figure 4. Output spectrum of RF IRM when 5G interference signal and satellite signal exist at the same time (measured at the output of RF IRM)
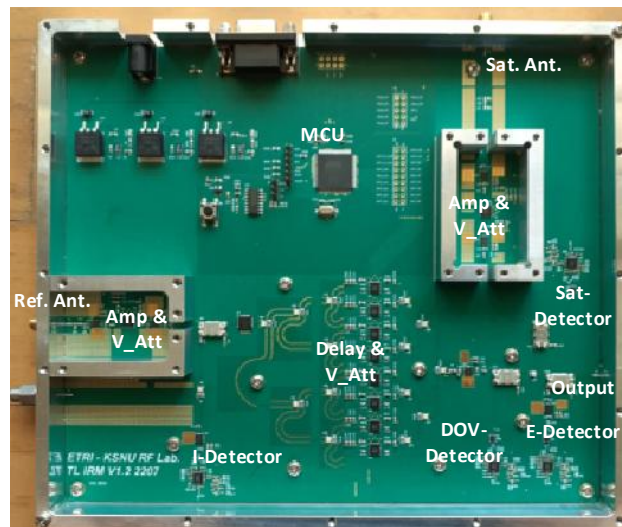
Figure 5. Photograph of the implemented wideband RF IRM

4. CONCLUSIONS

The design and implementation of RF IRM that can reduce the interference between transceivers providing different services in the same frequency band are presented. The implemented RF IRM can remove about 20dB of interference in the 100MHz bandwidth when only the interference signal exists. And when the 5G interference signal of -45dBm/100MHz and the satellite signal of -55dBm/40MHz exist at the center frequency of 3.83GHz at the same time, about 15dB of the 5G interference signal can be reduced in the frequency range where the satellite signal exists. If the method proposed in this paper is used, the interference effect of 5G signals on satellites can be actively reduced, and it can be used as an interference reducer in a similar environment.

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