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Performance of RF Interference Reduction Module in Indoor and Outdoor Environments

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Abstract

In this paper, the results of experiments conducted in indoor wired and outdoor wireless environments to reduce the interference impact of 5G mobile communication on fixed satellite services using RF Interference Reduction Module (IRM) are presented. Test results for interference signals with a 100MHz bandwidth in a wired environment demonstrate that RF IRM can reduce interference by more than 20dB in a 100MHz bandwidth. The performance of RF IRM was also tested in the S-band wireless environments. In the S-band wireless environments with interference signals having a 20MHz bandwidth, RF IRM exhibits interference reduction performance of 12-15dB, for signals with a 50MHz bandwidth, it shows 10-12dB interference reduction, and for signals with a 100MHz bandwidth, it demonstrates 5-10dB interference reduction. This paper shows that RF IRM can be used not only within transceivers but also in wireless environments to mitigate interference.

Keywords: *RF Interference, Interference Reduction, Interference Cancellation, Wideband, Transceiver*

1. Introduction

Interference always exists between wireless communication devices. Even when allocating new frequencies for providing new wireless services, it is necessary to consider the interference impact between wireless communication devices using adjacent frequency bands and the communication devices that intend to provide the new service. Especially in cases where interference is present, service should be provided after implementing measures to mitigate it. Common methods used to reduce interference between wireless communication devices are to physically separate them or establish frequency guard bands [1].

If interference effects between wireless communication devices can be reduced or eliminated, the conditions to be observed when introducing a new service are relaxed, ultimately leading to an increase in frequency utilization efficiency. Recent research has been conducted on Self-Interference Cancellation (SIC) technology as a means to reduce interference effects occurring within wireless communication devices [2, 3, 4, 5, 6]. SIC

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technology provides a means to reduce interference signals when the transmitter's signal interferes with the receiver. SIC technology can eliminate interference in both the RF and digital domains. It is a method for reducing interference effects caused by the transceiver itself and not a method for reducing interference effects between wireless communication devices. If interference between wireless communication devices can be reduced, it allows for more flexible service provision when offering new services and effectively increases frequency utilization efficiency.

Recently, 5G mobile communication frequencies have been allocated to the S-band, which is being used by fixed satellite communication services. Many studies have been conducted on the interference impact of 5G mobile communication on satellite communications [1,7,8,9,10]. This paper describes a RF IRM that can reduce the interference impact of 5G mobile communication systems on satellite communication services.

2. Implementation and Structure of RF IRM

A power combiner is a device that combines two input signals to produce an output signal. When two input signals with the same magnitude but a 180-degree phase difference are applied to the two input terminals of a power combiner, the signal output at the output terminal of the power combiner is reduced or cancelled. The degree to which the signal is reduced at the output of the power combiner is determined by the mismatch in magnitude, phase mismatch, and time delay mismatch of each path. This is the principle by which the interference signal is reduced or cancelled.

The operating principle of the RF IRM proposed in this paper is as follows Figure 1. In Figure 1, the satellite antenna can receive both satellite signals and 5G mobile communication signals, but the reference antenna receives only the 5G mobile communication signal. By adjusting the magnitude of the 5G mobile communication signal entering both the satellite antenna path and the reference antenna path and applying it to the subtraction circuit, the 5G mobile communication signal is reduced at the output of the subtraction circuit, allowing the desired satellite signal to be received.

The configuration and operation of the RF IRM proposed in this paper are described in reference [11]. The Delay & V_Att, consisting of an analog FIR(Finite Impulse Response) filter, has 8 ~ 16 paths, and with a delay resolution of about 1 ns, the interference reduction performance exceeds 20 dB [12]. The difference between reference [11] and the RF IRM implemented in this paper lies in the number of paths in the Delay & V_Att. Figure 2 shows a photograph of the RF IRM implemented in this paper, with 16 paths. Increasing the number of paths has the effect of expanding the overall range of delay that the RF IRM can accommodate, leading to better performance in outdoor environments compared to reference [11].

The configuration and operation of the RF IRM proposed in this paper are described in reference [11]. The Delay & V_Att serves the role of an analog FIR (Finite Impulse Response) filter and is composed of delay lines and variable attenuators, each with fixed and different delay times. Delay & V_Att is reported to have 8-16 paths and, with delay lines providing an approximate delay resolution of 1 ns, it is capable of achieving an interference reduction performance exceeding 20 dB [12]. The key difference between reference [11] and the RF IRM implemented in this paper lies in the number of paths within Delay & V_Att. Figure 2 displays a photograph of the RF IRM implemented in this paper, featuring 16 paths. Increasing the number of paths extends the overall range of delay that the RF IRM can handle, resulting in improved performance in outdoor environments compared to reference [11].

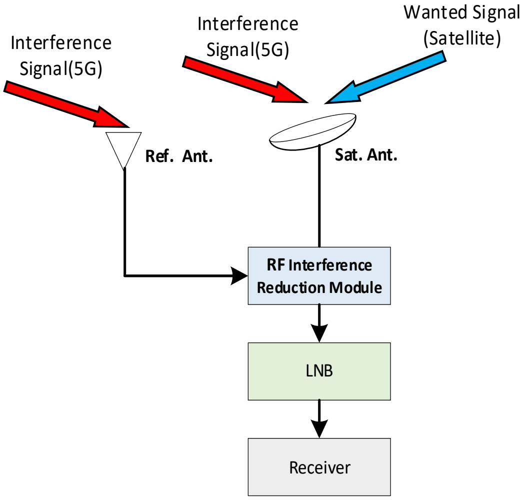


Figure 1. Operating Principle of the RF IRM

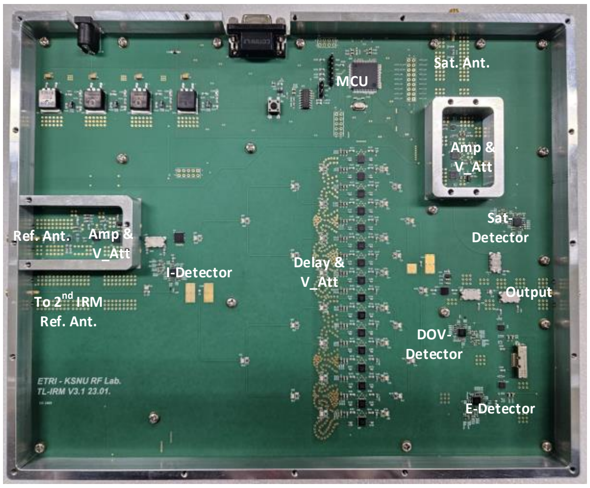


Figure 2. Photo of the Implemented RF IRM

3. Test Results of the RF IRM in Indoor and Outdoor Environments

The RF IRM was tested for its performance in both indoor wired and outdoor wireless environments. The outdoor wireless environment testing was conducted by installing a satellite antenna on the rooftop of RRA(National Radio Research Agency) in Naju city. The experimental setup in the wireless environment is shown in Figure 3. As seen in Figure 3, the added Bandpass Filter (BPF) in the front end of the RF IRM was used to remove SKT 5G signals in the 3.7GHz band that are being serviced around the RRA area.

Figure 4 shows the results of testing the performance of the RF IRM in the indoor wired environment, with the center frequency of the interference signal being the same as reference [11] at 3830MHz. The BPF has a relatively large delay time in the passband, and there is significant variation in delay time in the stopband. The performance of the RF IRM varies with delay time mismatch, so we conducted a performance experiment by adding two BPFs to both paths in the indoor wired environment, similar to the outdoor wireless environment. From Figure 4, it can be observed that in the wired environment, the RF IRM can reduce interference of over 20dB for interference signals in the 100MHz bandwidth, which matches the performance reported in reference [11].

Figures 5 ~ Figure 7 show the results of testing the performance of the RF IRM in the outdoor wireless environments. In the wireless environment, interference signals with bandwidths of 20MHz and 50MHz were tested for center frequencies at 3950MHz, 3960MHz, and 3970MHz, and interference signals with a 100MHz bandwidth were tested for center frequencies at 3950MHz and 3970MHz. The interference reduction performance of the RF IRM for interference signals with a 20MHz bandwidth is as depicted in Figure 5. Figure 5 illustrates that the RF IRM reduces interference signals with a 20MHz bandwidth by 12~15dB. The interference reduction performance for interference signals with a 50MHz bandwidth and interference signals with a 100MHz bandwidth is the same as shown in Figure 6 and Figure 7, respectively. From Figure 6 and Figure 7, it can be observed that the RF IRM reduces interference signals with a 50MHz bandwidth by 10~12dB and interference signals with a 100MHz bandwidth by 5~10dB. The photographs of the interference transmitter, the satellite antenna, and the reference antenna used in the wireless environment testing are shown in Figure 8.

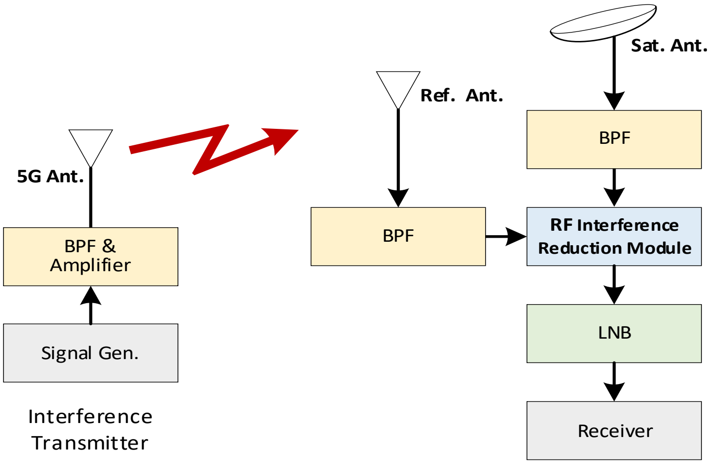


Figure 3. Test Setup for the RF IRM in Outdoor Environments

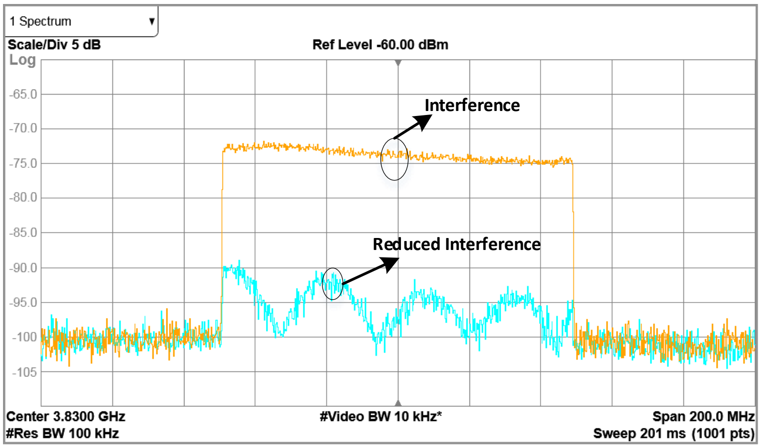
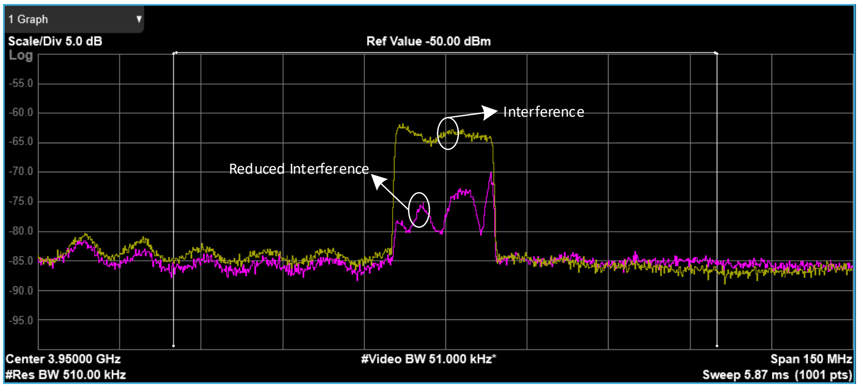
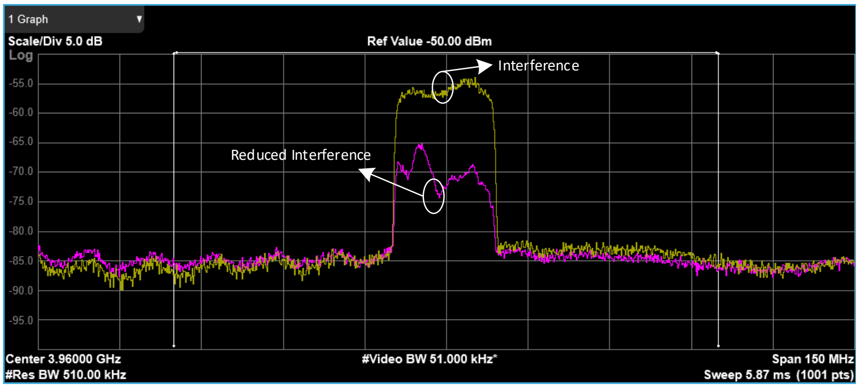


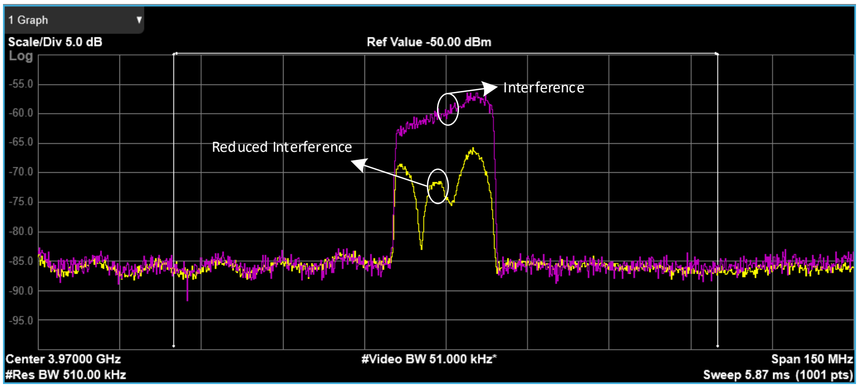
Figure 4. Interference Reduction Performance for Interference Signals with a 100MHz Bandwidth in Indoor Wired Environments (Using Waveguide BPF in both paths)



(a) Center frequency: 3950MHz

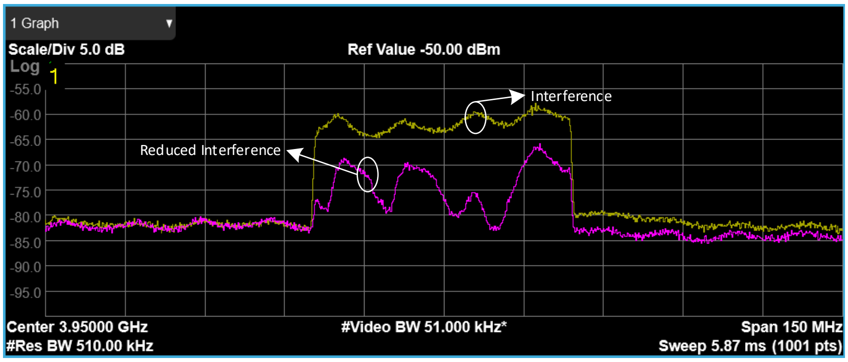


(b) Center frequency: 3960MHz

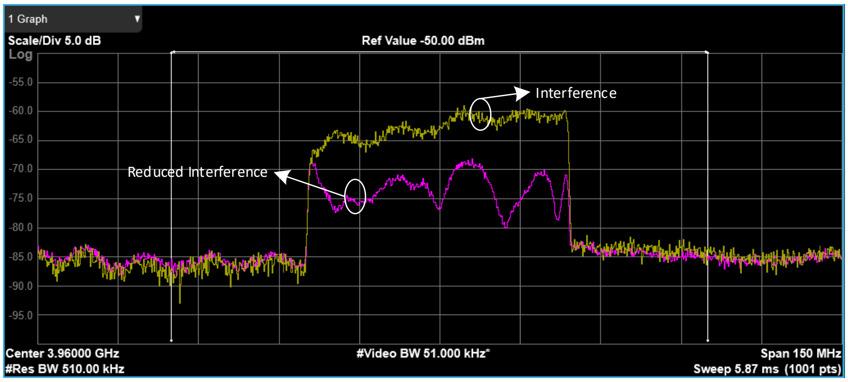


(c) Center frequency: 3970MHz

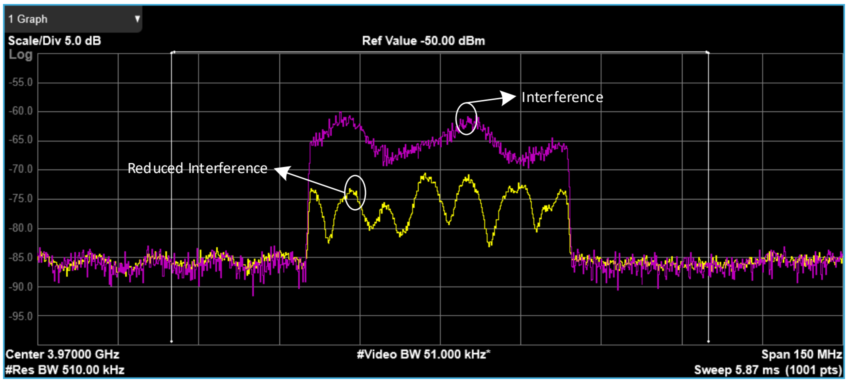
Figure 5. Interference Reduction Performance for Interference Signals with a 20MHz Bandwidth



(a) Center frequency: 3950MHz

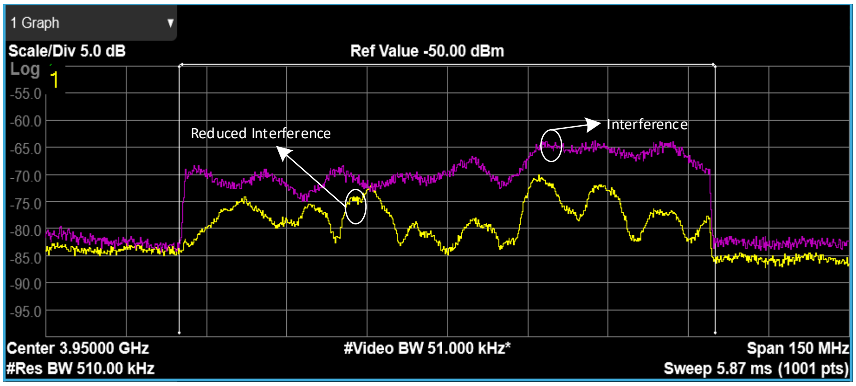


(b) Center frequency: 3960MHz

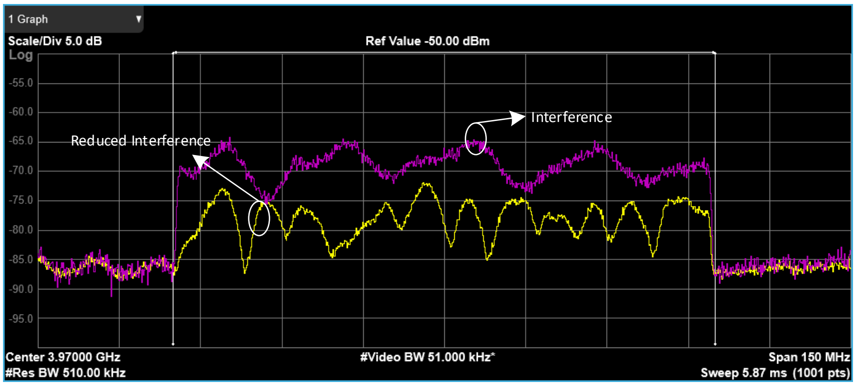


(c) Center frequency: 3970MHz

Figure 6. Interference Reduction Performance for Interference Signals with a 50MHz Bandwidth



(a) Center frequency: 3950MHz



(b) Center frequency: 3970MHz

Figure 7. Interference Reduction Performance for Interference Signals with a 100MHz Bandwidth

(a) Interference Transmitter **(b) Satellite Antenna and Reference Antenna**

Figure 8. Photos of Interference Transmitter, Satellite Antenna and Reference Antenna Used in the Outdoor Wireless Environments

4. Conclusions

The RF IRM proposed in this paper demonstrates the ability to reduce interference by over 20dB for interference signals with a 100MHz bandwidth in a wired environment. In a wireless environment, the performance of the RF IRM was tested for interference signals with center frequencies at 3950MHz, 3960MHz, and 3970MHz, having bandwidths of 20MHz and 50MHz, as well as interference signals with a 100MHz bandwidth centered at 3950MHz and 3970MHz. The experimental results show that in a wireless environment, interference signals with a 20MHz bandwidth experience a reduction of 12~15dB, those with a 50MHz bandwidth experience a reduction of 10~12dB, and for interference signals with a 100MHz bandwidth, a reduction of 5~10dB is achieved.

Acknowledgement

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