Measurements on FM Waves From Japan and Korea for Estimating Overreach Interference Sources of Terrestrial TV Waves

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***Abstract*—In western Japan, UHF band terrestrial digital TV waves have been sometimes affected by co-channel overreach interferences from Korea. To evaluate the co-channel interferences, we have proposed a new method monitoring both RSSI (Received Signal Strength Indicator) and CNR (Carrier to Noise power Ratio) of the digital TV waves and RSSI of FM broadcasting waves at the same time and we installed the measurement system at KIT (Kyushu Institute of Technology) in Fukuoka prefecture. At the measurement point, there are some candidates of overreach interference sources transmitting TV waves with same frequency, not only in Korea but also in Japan. In this study, we tried to estimate the overreach interference sources based on our proposed method monitoring FM waves transmitted from stations nearby the several candidates of interference sources. From the measurement results, it was found that the main overreach interference was from Korea, and that the main factor of the interference was an atmospheric duct propagation occurred over the sea.**

Keywords—terrestrial digital broadcasting; FM broadcasting; overreach interference; duct propagation; RSSI; CNR

I. INTRODUCTION

In digital terrestrial TV broadcastings, almost the same UHF (Ultra High Frequency) bands have been assigned in both Japan and Korea. Therefore it is important to investigate overreach characteristics of UHF band TV waves to keep a reception quality of the TV services. In Kyushu and Chugoku region, western Japan, there exists some co-channel interference of TV waves from Korea[1]. To detect the overreach interference in TV waves, other group developed the device that can analyze an ID of interference TV waves from the received signals[2]. However, the broadcasting scheme in Korea is ATSC (Advanced Television Systems Committee standards) [3][4] that is different from the scheme in Japan ISDB-T (Integrated Services Digital Broadcasting-Terrestrial)[5]. Therefore the overreach propagation superimposes the TV waves from Korea on Japanese TV waves as broadband noises. In this case, it is impossible to analyze the ID and identify a source of interference from Korea.

To overcome the above problems in identifying the source of the interference, the authors have proposed a measurement method monitoring both RSSI (Received Signal Strength Indicator) and CNR (Carrier to Noise power Ratio) of the digital TV waves and RSSI of FM broadcasting waves from several cities at the same time[6][7]. The proposed method is based on our previous measurement result that there are high correlation in non-LOS (Line-Of-Sight) propagations between VHF band FM waves and UHF band TV waves. So the proposed method has a possibility to identify the source of interference TV waves from Korea. Based on the proposed method, we developed the measurement system to evaluate the co-channel interference in digital TV waves, and installed the system at KIT (Kyushu Institute of Technology) in Fukuoka prefecture. At the measurement point, there are some candidates of overreach interference sources or stations transmitting TV waves with same frequency, not only in Korea but also in Japan.

In this study, we tried to estimate the overreach interference sources based on our proposed method monitoring FM waves transmitted from stations nearby the several candidates of interference sources, Busan in Korea, Yamaguchi, Ehime, Nagasaki in Japan. From the measurement results, it was found that the main overreach interference was from Busan, and that the main factor of the interference was a duct propagation caused by an inverse layer in atmospheric refractivity over the sea.

II. PROPOSED METHOD FOR ESTIMATING OVERREACH INTERFEREANCE OF TV WAVES USING FM WAVES

The proposed method measures RSSI and CNR of TV waves to detect the overreach interference in the digital TV and simultaneously measures RSSI of FM waves transmitted from stations near the candidates of TV stations to identify the source of the overreach interference of TV waves. Fig 1 illustrates the concept of identifying the source of the interference based on RSSI and CNR data.

In the standard state, where there is no overreach interference, the CNR is measured as the ratio of the RSSI of the desired digital TV waves to the noise power in the receiver. In this case, if the RSSI of the desired TV wave fluctuates, the CNR also changes almost in the same way, because the noise power in the receiver is almost stable. On the other hand, under the condition of overreach interference, the RSSI of undesired

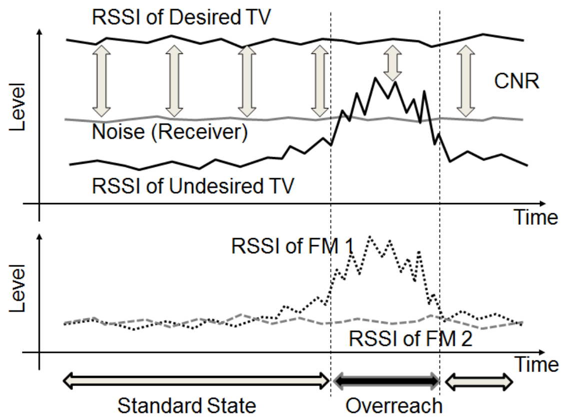

Fig. 1 The concept of identifying a source of interference based on RSSI and CNR of TV and FM waves.

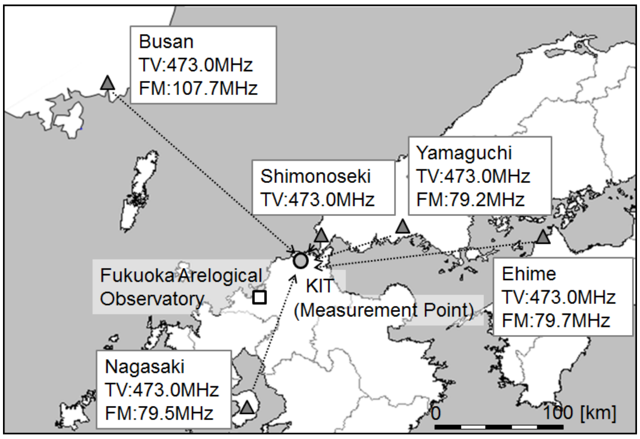

Fig. 2 Locations of the measurement point and the broadcasting stations of TV and FM waves

TV wave increases over the level of noise power as shown in the upper part of Fig. 1, and the CNR decreases at the same time. The proposed method makes a judgmental decision that the desired TV waves are affected by the overreach interference, when the CNR of the TV waves decreases in spite of stable RSSI variation.

To identify the source of the undesired TV waves, the proposed method also monitors RSSI of FM waves as shown in the lower part of Fig. 1. Under condition of overreach interference, the method compares the RSSI of FM 1 and FM 2 waves, which are transmitted from stations near the candidates of undesired TV wave stations and distinguished from each other because these FM waves use different frequency. If the RSSI of FM1 is larger than that of FM2 as shown in Fig. 1, the proposed method can identify that the source of the undesired TV waves is the transmission station near the FM1 transmission site.

III. Measrurement Environment

Fig. 2 depicts the measurement environment showing locations of broadcasting stations of TV and FM waves and our measurement point installed at KIT. At the measurement point, the TV wave from Shimonoseki is able to be received. The TV wave of 473 MHz from Shimonoseki is desired one in this measurement. The 473 MHz channels are also assigned to other TV waves both in Korea and Japan. As shown in Fig. 2, co-channel 473 MHz TV waves are broadcasted from Busan in Korea, Yamaguchi, Ehime, and Nagasaki in Japan. Therefore, in this case, Busan, Yamaguchi, Ehime and Nagasaki TV stations are candidates of overreach interference sources. Near these TV stations, there are FM stations transmitting FM broadcasting waves. Since the frequencies of these FM waves are not assigned to any other FM waves around the southern part of Korea and the western part of Japan, our proposed method can identify the source of overreach TV waves from the interference candidates by measuring RSSI of these FM waves.

TABLE I. Specifications of TV and FM stations

	Measurement Freq.	Station	Power
TV	473 MHz	Shimonoseki	100 W
		Busan	2.5 kW
		Yamaguchi	10 kW
		Ehime	2.5 kW
		Nagasaki	10 kW
FM	107.7 MHz	Busan	3 kW
	79.2 MHz	Yamaguchi	1 kW
	79.7 MHz	Ehime	1 kW
	79.5 MHz	Nagasaki	1 kW

TABLE II. Specifications of Measurement System

	UHF-TV RSSI	VHF-FM RSSI	UHF-TV CNR
Measurement Limitation	-110 dBm	- 120 dBm	-105 dBm
Sampling Interval	2 sec		1 sec
Receiving Antenna	Monopole (from VHF to UHF)		

Main specifications of the TV and FM broadcasting stations and the measurement system are shown in Table 1 and 2. The broadcasting powers of interference candidates of TV waves are 2.5 kW or 10 kW. And the broadcasting powers of FM waves measured in this trial are 1 kW or 3 kW. At the measurement point, we can listen to the demodulated sounds of the FM waves at all times. In this measurement, these TV and FM waves are received with a monopole antenna (gain: 0dB) set up on the rooftop of the building in KIT. Using broadband receivers (for RSSI) and digital 1-Seg TV tuners (for CNR), RSSI of TV and FM waves and CNR of TV waves are recorded in the PC. And we can remotely control the PC and transfer recorded RSSI and CNR data from KIT to our university through the Internet and a communication network.

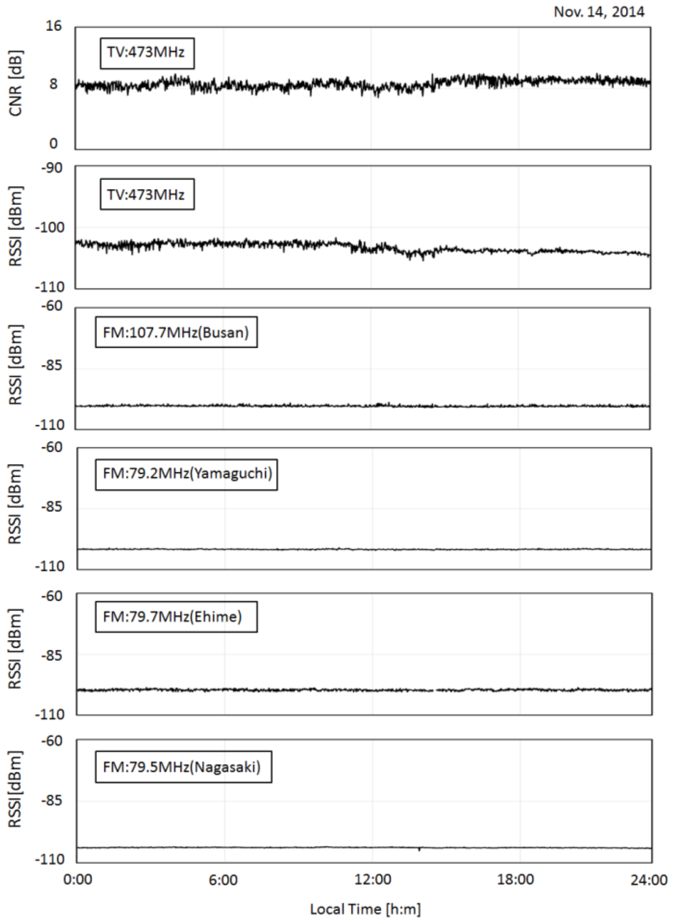

Fig. 3 Typical results of standard propagations of TV and FM waves recorded on Nov. 14, 2014

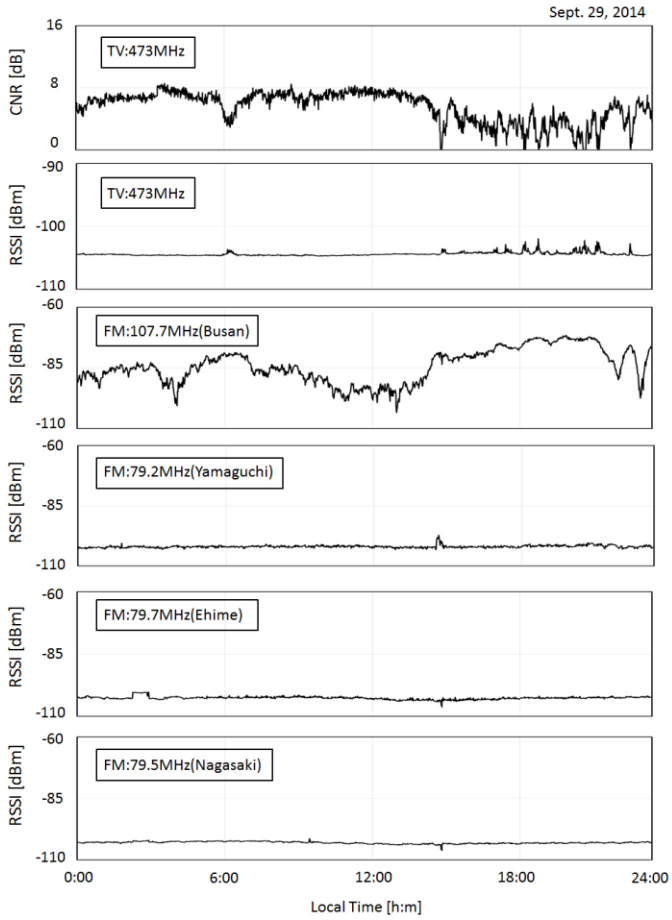

Fig. 4 Typical results of overreach propagations of TV and FM waves recorded on Sept. 29, 2014

IV. MEASUREMENT RESULTS

After starting measurement from September in 2014, we observed CNR degradations due to overreach interferences in TV waves many times. This section shows the typical results of the variations in CNR and RSSI of TV and FM waves under conditions of standard and overreach propagations.

Fig. 3 shows the typical measurement results of standard propagation recorded on Nov. 14, 2014. The results are CNR and RSSI of 473 MHz TV waves and RSSI of FM waves from Busan, Yamaguchi, Ehime, and Nagasaki, respectively. As shown in Fig. 3, all the level of CNR and RSSI were almost stable. Since the CNR of TV waves didn't decrease, it was estimated that overreach propagation didn't occur and the TV waves were not affected by co-channel interferences.

The typical results of overreach propagation were recorded on Sept. 29, 2014 as shown in Fig. 4. From the top graph of Fig. 4 we found that CNR variations had all-day fluctuations and large degradations from 15:00 to 23:00 JST. On the other hand, RSSI variations of the TV waves were almost stable with small fluctuations as shown in the second graph of Fig. 4. These CNR and RSSI variations indicate that the desired TV waves were affected by overreach interferences and the receiving quality of the TV waves was reduced by the interferences. From other graphs showing RSSI of FM waves in Fig. 4, we can identify the source of the interference of TV waves. Comparing the RSSI variations of the FM waves from Busan, Yamaguchi, Ehime and Nagasaki, we can find that the RSSI fluctuation of the FM waves from Busan is the largest of all. While the RSSI of FM waves from Yamaguchi, Ehime and Nagasaki were almost stable, the RSSI of FM waves from Busan has large fluctuations especially from 15:00 to 23:00 JST. From Fig. 4, it was estimated that the source of the overreach interference in TV waves was Busan on Sept. 29, 2014. As a reason that the overreach propagations hardly occur from Yamaguchi, Ehime and Nagasaki to KIT, difference of path profiles are considered. As shown in Fig. 1, the propagation path from Busan is almost over the sea, while the paths from other sites include land and mountain areas. The land and mountain propagation paths contribute a larger diffraction loss. In our other measurement results, the RSSI of FM waves from Yamaguchi, Ehime, and Nagasaki have not increased ever.

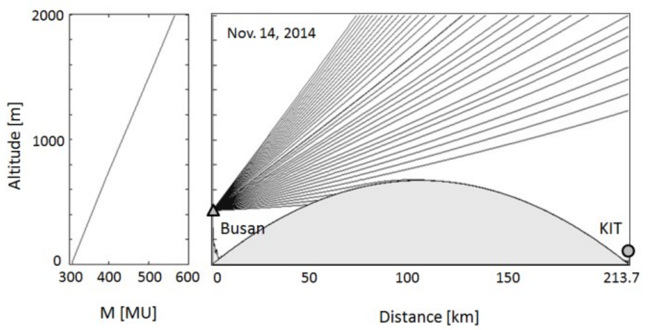

Fig. 5 Ray-tracing simulation results of standard propagations from Busan to KIT calculated by aerological data on Nov. 14, 2014.

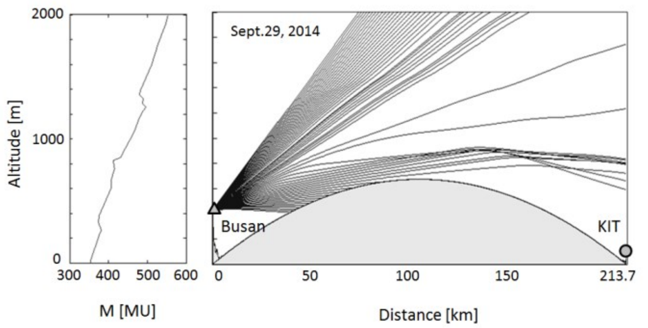

Fig. 6 Ray-tracing simulation results of overreach propagations from Busan to KIT calculated by aerological data on Sept. 29, 2014.

To evaluate overreach propagation from Busan, we tried to do simulations by ray-tracing method. In the simulations, to create M profiles (height patterns of modified atmospheric refractivity M), we utilized aerological data observed in Fukuoka Aerological Observatory of the Meteorological Agency[8]. The location of the observatory is shown in Fig. 2. The simulation results based on the aerological data on Nov. 14 and Sept. 29, 2014 are shown in Fig. 5 and Fig. 6, respectively. As shown in Fig. 5, the M profile was linear on Nov. 14, and the radio propagation rays were almost straight because of the standard atmosphere with $k = 4/3$, where k is the effective Earth radius factor. On the other hand, as shown in Fig. 6, on Sept. 29, 2014, the M profile had an inverse layer producing an atmospheric duct propagation[9], and the propagation rays were refracted in the duct propagation. From these results, it was found that the atmospheric duct propagation caused the overreach interference in the TV waves.

V. Conclusions

In this study, we tried to estimate the overreach interference sources based on our proposed method monitoring FM waves transmitted from stations nearby the several candidates of interference sources, Busan in Korea, Yamaguchi, Ehime, Nagasaki in Japan. From the measurement results, it was found followings;

- The source of the interference of TV waves was identified by our proposed method.
- The overreach interferences of TV waves were mainly from Busan in Korea, not from Japan.
- Ray-tracing simulation results indicated that the the overreach interferences were caused by the atmospheric duct propagation.

Acknowledgment

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