PERFORMANCE OF AN INTERFERENCE CANCELLATION SYSTEM USING THE IN-BAND POWER MINIMIZING METHOD

Kenichi MINAMISONO, Fumio WATANABE, Noboru BABA and Takayasu SHIOKAWA
KDD Meguro R&D Laboratories
2-1-23, Nakameguro, Meguro-ku, Tokyo 153, Japan

1. Introduction

Recently, business satellite services have attracted a great deal of attention. With this type of service, customers have direct satellite access via the small earth stations installed in their premises in urban areas. However, as the same frequency band, such as the 11GHz band, is allotted to both satellite service links and terrestrial microwave links, it sometimes becomes an important problems to develop the techniques which can reduce interference from the terrestrial links effectively.

Adaptive arrays or adaptive sidelobe cancellers[1]-[4] seem to be the effective techniques to reduce interference. Research on these techniques has been carried out by many organizations so far. At this stage, these techniques are attractive academically, however, seem to be premature from the practical viewpoints.

First of all in this paper, we propose a new type of interference cancellation technique named IPMM (In-band Power Minimizing Method)[5]. In spite of the simple configuration, the technique is applicable for the system with low signal-to-noise ratio, which is a suitable feature for small earth stations. And also we present the performance characteristics of an experimental system and discuss the cancellation effects.

2. Principle of the IPMM

A functional block diagram of the interference cancellation system based on the IPMM is shown in Figure 1. In this figure, the signal from the main antenna consists of the desired signal s(t), the interference signal i(t) and the noise signal n(t). The signal received by the auxiliary antenna also consists of a desired signal $s_a(t)$, an interference signal $i_a(t)$ and a noise signal $n_a(t)$, but in most cases, signals $s_a(t)$ and $n_a(t)$ are negligible compared with signal $i_a(t)$.

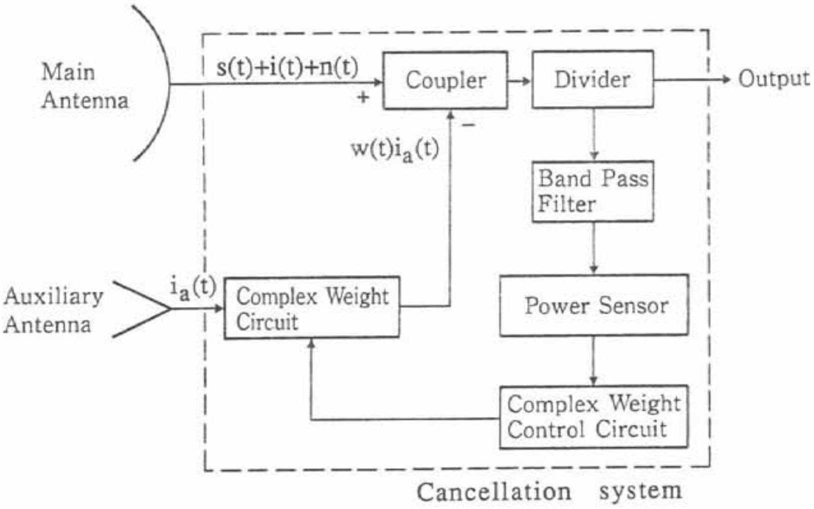

Figure 1: Functional block diagram of the interference cancellation system based on the IPMM

Assuming that the signals s(t), i(t), and n(t) are not correlated with each other, and that the signals i(t) and $i_a(t)$ have the relation

$$i_a(t) = k(t)\ i(t)\ e^{-j\theta(t)} \qquad (1)$$

k(t) : amplitude ratio of two signals

θ(t) : phase difference between these signals,

the output signal z(t) and the mean power of the output signal p(z,T) can be expressed as

$$z(t) = s(t) + \{\ 1 - w(t)k(t)e^{-j\theta}\}\ i(t) + n(t) \qquad (2)$$

$$p(z,T) = p(s,T) + p(\ (1-wke^{-j\theta})\ i,\ T) + p(n,T) \qquad (3)$$

$$p(x,T) = \frac{1}{T}\int_{t_0}^{t_0+T} |x(t)|^2 dt, \qquad (4)$$

where w(t) represents the complex weight to be determined.

Equation (3) implies that the residual interference signal in the output signal could be cancelled if the complex weight w(t) were determined so as to minimize the output signal power, p(z,T).

In the IPMM, the complex weight w(t) is determined to minimize the output signal power, p(z,T). Since several 2-dimensional minimizing algorithm are applicable, the IPMM can be easily implemented using a microprocessor. In the experimental system, 2-dimensional step tracking is adopted to determine the weight, w(t), adaptively in the following manner, namely,

(1) Set an initial complex weight w_0 and measure the output power.

(2) Displace the weight by w_0+dw_i and measure the output power. This step is repeated for a set of the complex displacement $\{\ dw_0\ \ dw_1\ ...\ dw_i\ ...\ dw_q\ \}$.

(3) Compare the measured values obtained by steps (1) and (2). The optimum weight which will minimize the output power is forecasted.

(4) Repeat step (1) using the forecasted optimum weight.

3. Experiments

3.1 Experimental system

In the business satellite service, digital transmission technology is fully applied. In our experiment, a 64Kbps digital carrier is looped back at the radio frequency and is used as a desired signal. On the other hand, the 11GHz band signal from the terrestrial microwave links, which are received by sidelobe of an offset antenna with 1.2m diameter, is used as an interference signal.

Figure 2 shows a block diagram of the experimental system. A PSK MODEM with rate 1/2 FEC is used. To evaluate the effect of the interference cancellation system, the timer-controlled RF switch is inserted to the auxiliary channel so as to operate or suspend the cancellation. The mean signal levels are also shown in Table 1.

3.2 Experimental results

Figure 3 shows an example of the interference cancellation effect. As cen be seem from this figure, the interference signal level is reduced by more than 15dB and becomes approximately the noise level. Table 2 and shows the 1-minute bit error rate (BER) performance of the desired signal. Under normal weather condition (Table 2-a), more then 80 percent of data became error free with cancellation and the percentage of data with BER over 10^{-3} was reduced to 11 percent, compared to more then 90 percent of data had a BER over 10^{-3} without cancellation. Since the great improvement of BER performance was obtained. it may be concluded that the technique is applicable to the practical interference cancellation systems. But the cancellation effect was reduced by rainfall or strong wind (Table 2-b), which was due to a degradation of correlation between interference signals received by the main and the auxiliary antennas (Eq. (1)). This difficulty can be overcome by improving a response time of the experimental system.

4. Conclusion

In this paper, a newly developed interference cancellation technique called IPMM, in which the complex weight is controlled so that the output signal power is minimal, was proposed and its performance characteristics was described. As a result, a more than 15dB cancellation was obtained for actual terrestrial microwave signals, and a good improvement of the bit error performance was obtained for the desired 64Kbps signal. It can be noticed that this technique is recommendable for practical systems.

The authors would like to express their sincere gratitude to Mr. K. Komuro and Dr. M. Yamada of KDD for their continuous guidance and encouragement.

---References---

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Table 1 : Mean signal levels.

Signal	Level
Desired signal (C)	-56dBm
Interference signal (I)	-50dBm
Noise signal (N_0)	-118dBm/Hz
C/N_0	62dBHz
C/I	-6dB

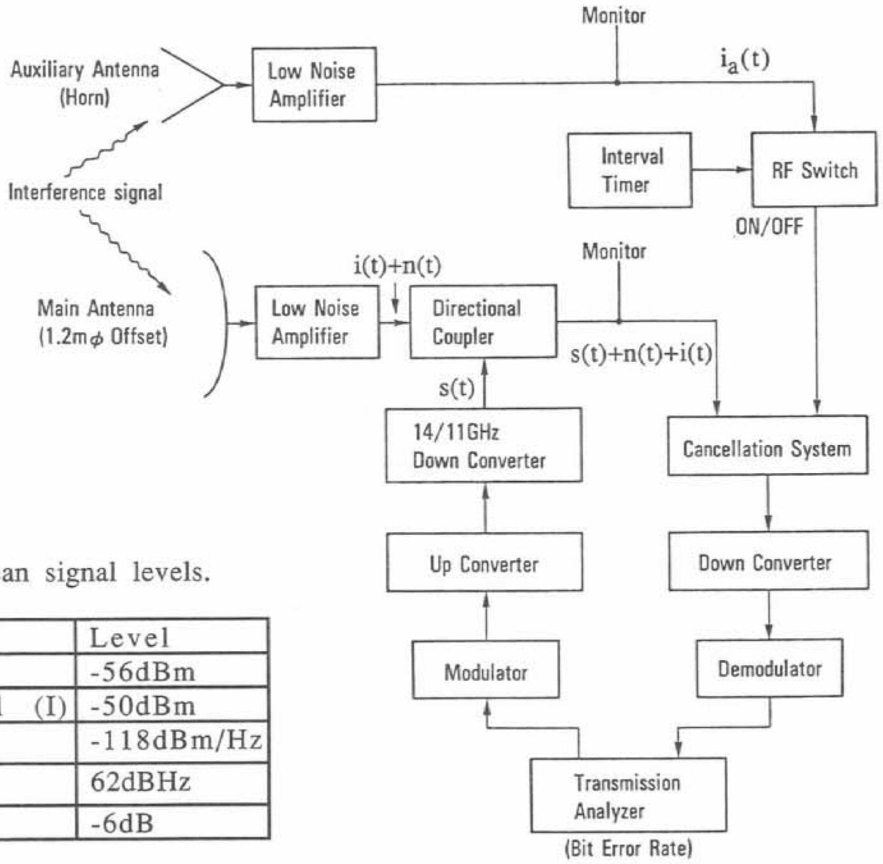
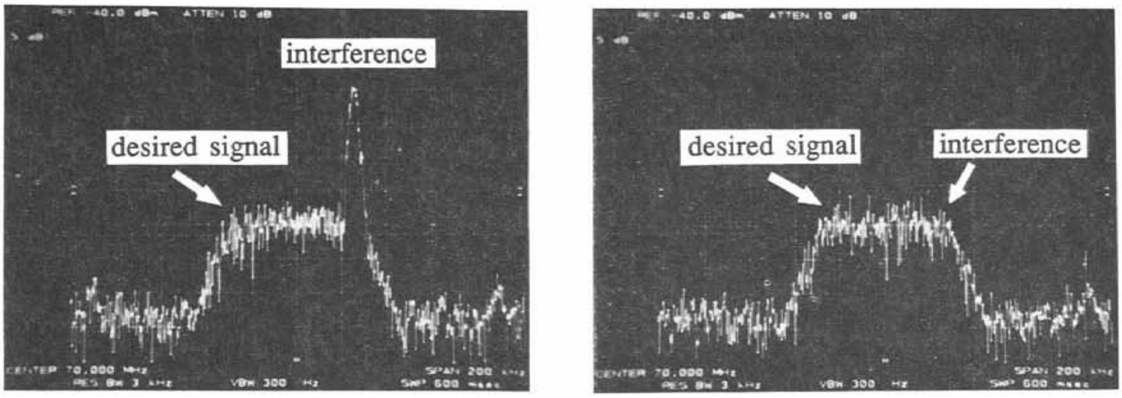


Figure 2: Block diagram of the experimental system.



(a) Output signals without cancellation. (b) Output signals after cancellation.

center frequency : 70MHz (RF 10.955MHz)
frequency span : 200KHz
resolution bandwidth : 3KHz
video bandwidth : 300Hz
reference level : -40dBm
vertical : 5dB/div

Figure 3 : An example of the interference cancellation effect.

Table 2-a : A bit error rate performance under normal weather condition.

Bit error rate	with cancellation		without cancellation	
	No. of data	% of data	No. of data	% of data
$3.0\text{x}10^{-2}$<=BER	1	0.90	98	89.08
$1.0\text{x}10^{-2}$<=BER< $3.0\text{x}10^{-2}$	2	1.80	3	2.73
$3.0\text{x}10^{-3}$<=BER< $1.0\text{x}10^{-2}$	4	3.60	0	0.00
$1.0\text{x}10^{-3}$<=BER< $3.0\text{x}10^{-3}$	5	4.50	1	0.91
$3.0\text{x}10^{-4}$<=BER< $1.0\text{x}10^{-3}$	4	3.60	0	0.00
$1.0\text{x}10^{-4}$<=BER< $3.0\text{x}10^{-4}$	0	0.00	1	0.91
$3.0\text{x}10^{-5}$<=BER< $1.0\text{x}10^{-4}$	0	0.00	1	0.91
$1.0\text{x}10^{-5}$<=BER< $3.0\text{x}10^{-5}$	1	0.90	1	0.91
$3.0\text{x}10^{-6}$<=BER< $1.0\text{x}10^{-5}$	1	0.90	0	0.00
$1.0\text{x}10^{-6}$<=BER< $3.0\text{x}10^{-6}$	0	0.00	0	0.00
BER< $1.0\text{x}10^{-6}$	93	83.80	5	4.55
Total	111	100.00	110	100.00

Table 2-b : A bit error rate performance under rainy condition.

Bit error rate	with cancellation		without cancellation	
	No. of data	% of data	No. of data	% of data
$3.0\text{x}10^{-2}$<=BER	38	19.79	98	51.04
$1.0\text{x}10^{-2}$<=BER< $3.0\text{x}10^{-2}$	34	17.71	26	13.54
$3.0\text{x}10^{-3}$<=BER< $1.0\text{x}10^{-2}$	20	10.42	15	7.81
$1.0\text{x}10^{-3}$<=BER< $3.0\text{x}10^{-3}$	18	9.38	18	9.38
$3.0\text{x}10^{-4}$<=BER< $1.0\text{x}10^{-3}$	26	13.54	7	3.65
$1.0\text{x}10^{-4}$<=BER< $3.0\text{x}10^{-4}$	4	2.08	0	0.00
$3.0\text{x}10^{-5}$<=BER< $1.0\text{x}10^{-4}$	0	0.00	3	1.56
$1.0\text{x}10^{-5}$<=BER< $3.0\text{x}10^{-5}$	1	0.52	2	1.04
$3.0\text{x}10^{-6}$<=BER< $1.0\text{x}10^{-5}$	6	3.13	2	1.04
$1.0\text{x}10^{-6}$<=BER< $3.0\text{x}10^{-6}$	0	0.00	0	0.00
BER< $1.0\text{x}10^{-6}$	45	23.43	21	10.94
Total	192	100.00	192	100.00