PERFORMANCE OF CROSS POLARIZATION CANCELER WITH TRANSVERSAL FILTERS

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INTRODUCTION

Co-channel dual-polarization is one of the most effective ways to increase frequency utilization of digital radio systems, since co-channel dual-polarization digital radio systems can double the capacity of a route. However, system performance is severely degraded by cross polarization (cross-pol) interference during multipath fading. Under such conditions, cross-pol cancelers (Refs. 1,2) have the advantage of improving the system performance.

Recently, several experiments were carried out to determine the detailed frequency characteristics of the wideband cross-pol interference in digital microwave radio systems (Refs. 3-5). The results show that the cross-pol interference is more dispersive than the cross-pol signal, and that the dispersions for the cross-pol signal and the cross-pol interference are not well correlated during multipath fading.

To overcome such cross-pol interference, a new cross-pol interference canceler has been developed. This paper presents the cross-pol canceler's fundamental operation and performance in laboratory and field tests. It is introduced into a 100 km span overwater digital radio system (Ref. 6), which will be in commercial use on the long span microwave radio-relay route to Okinawa island, at the southern end of Japan, in 1985.

FUNDAMENTAL OPERATION

During multipath fading, the cross-pol interference cannot be canceled sufficiently by the cross-pol signal with a simple adjustment of its amplitude and phase, since the frequency characteristics of the cross-pol interference are different from those of the original cross-pol signal.

Figure 1 illustrates the fundamental operation of the new cross-pol interference canceler that is suitable for such cross-pol interference.

The new cross-pol interference canceler has a transversal filter as a frequency characteristic converter as shown in Fig. 1. The converter transforms the cross-pol signal frequency characteristics to the cancelling signal's ones, which resemble the cross-pol interference frequency characteristics. Therefore, the interference can be sufficiently suppressed by the cancelling signal. The transversal filter is adaptively controlled by a simple digital circuit adopting the zero-forcing algorithm, which is used widely as the transversal equalizer control algorithm.

CANCELER PERFORMANCE

Laboratory Tests

The following types of laboratory experiments were performed on the cross-pol interference canceler (XPIC) to establish its fundamental performance characteristics:

(type 1) dispersive cross-pol interference and flat cross-pol signal,
(type 2) flat cross-pol interference and dispersive cross-pol signal.

The experiment's configuration is shown in Fig. 2. Two sets of 50 Mb/s 16 QAM modems were used to generate and demodulate the in-line and cross-pol signals, of which IF center frequency was 150 MHz. The IF band cross-pol canceler had 5-tap transversal filters as frequency characteristic converters. The dispersive frequency characteristics were generated by the static fading simulator based on the two-ray fading model. On the fading simulator, fading notch depth (D_{dip}), notch frequency (F_{dip}), and delay difference (τ) could be varied.

In the type 1 experiment, the least amount of cross-pol cancellation improvement occurred where F_{dip} was at the center frequency of 150 MHz and D_{dip} was the maximum value of 55 dB on the fading simulator. Under the same condition, the cancellation improvement with a variable delay difference was measured at a 10^{-4} bit error rate (BER) with a CNR of 21 dB. The relationship of the improvement factor to the delay difference is shown by the solid line in Fig. 3. The cross-pol interference was suppressed by the flat cross-pol signal by a factor of 15 dB though it was dispersed worst due to the the fading with the D_{dip} of 55 dB, and the improvement factor did not depend on the delay difference.

In the type 2 experiment, the cancellation improvement reduced least at an F_{dip} of 153 MHz with a D_{dip} of 20 dB. The improvement was measured in the same way as in the type 1 experiment, as shown by the dashed line in Fig. 3. The improvement factor decreased drastically as the delay difference increased, though D_{dip} in the type 2 experiment was lower than D_{dip} in the type 1 experiment by a factor of 35 dB. In fact, the type 2 condition looks like the dominant factor in the degradation of the cross-pol discrimination (XPD), and it is one of the worst conditions for the canceler to compensate for. Therefore, the type 2 experiment should be taken into account in designing the cross-pol canceler.

Moreover, the type 2 statistical experiment was performed under multipath fading conditions. The following dynamic fading simulator conditions were assumed:

(1) multipath fading was manifested by the two-ray model,
(2) probability density functions of amplitude ratio and phase difference of two rays were uniform in the range between $0.5 \sim 1.5$ and $0 \sim 2\pi$, respectively,
(3) the two-ray delay difference was fixed at 10 ns,
(4) fades of the in-line signal and the cross-pol signal were the same.

Above mentioned condition (2) is the severest fading condition in laboratory test.

In this experiment, two kinds of cross-pol cancelers were tested. One contained 5-tap transversal filters and the other 3-tap transversal filters. Adaptive 5-tap transversal equalizers were used to compensate for multipath fading dispersion. Outage probability at a 10^{-4} BER with XPD is presented in Fig. 4. At the same outage probability, XPD improvement factors for the cancelers using 5-tap and 3-tap transversal filters were 6 dB and 5 dB, respectively. Also, at the same XPD, outage probabilities for the cancelers improved by factors of 2 and 1.7, respectively.

Field Tests

The field experiments were conducted on the 97 km overwater span between Hanase and Kuchierabu in the Okinawa microwave radio-relay route. The power ratio of the direct ray to the reflected ray was 5.4 dB. The delay difference between the two rays was 9 ns.

From the transmitting site, 50 Mb/s 16 QAM in-line and cross-pol signals were transmitted at the 5 GHz band. At the receiving site, the signals were received by two antennas and combined to minimize inband amplitude dispersion (Refs. 6,7). The IF band 5-tap transversal equalizers were equipped for multipath fading dispersion. Two kinds of cross-pol cancelers containing the 5-tap and the 3-tap transversal filters were located after the transversal equalizers.

The cumulative distributions of BER with and without the cancelers are shown in Fig. 5. The 5-tap and the 3-tap cancelers reduced outage probability (BER 10^{-4}) by factors of 5 and 4, respectively. These agreed with the laboratory statistical experiment's factors though they increased slightly more than the laboratory ones.

CONCLUSION

A new cross-pol interference canceler using a transversal filter has been developed to reduce the cross-pol discrimination degradation during multipath fading. Laboratory and field tests were performed on the canceler. In the laboratory tests, the canceler performance was measured in two types of experiments. As a result, the cancellation improvement drastically decreased under the condition where the cross-pol signal was dispersed by multipath fading. This condition was one of the least improvement conditions for the canceler's performance. Therefore, this worst condition should be taken into consideration in designing this type of canceler. Moreover, under the same condition, a statistical experiment was performed. The canceler using 5-tap transversal filters improved XPD by a factor of 6 dB and reduced the outage probability by a factor of 2. In the field tests, the canceler reduced the outage probability by a factor of 5. It was confirmed that the field test improvement factor agreed with the statistical experiment's one.

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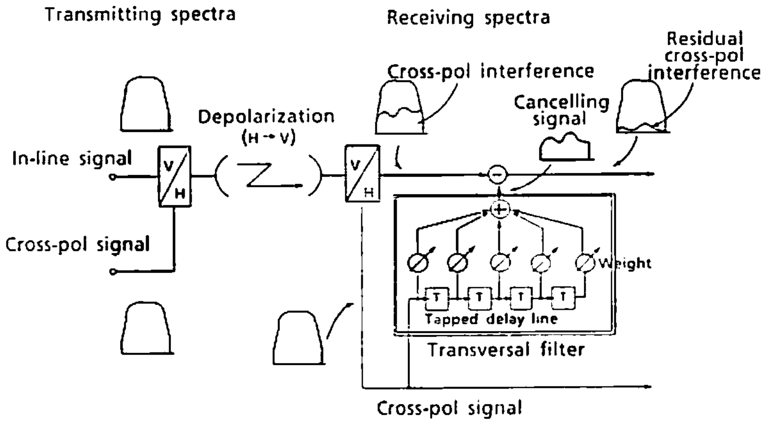

Fig. 1 Fundamental Operation

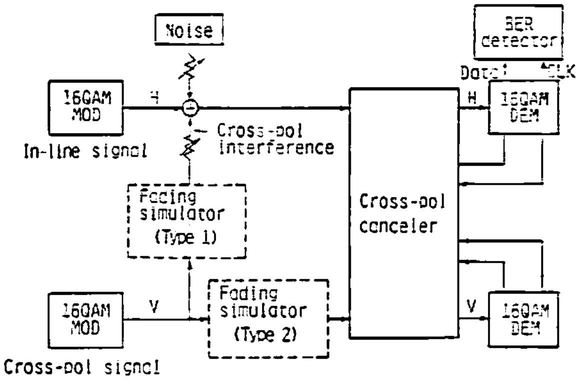

Fig. 2 Laboratory Experiment Configuration in Type 1 and Type 2 Experiments

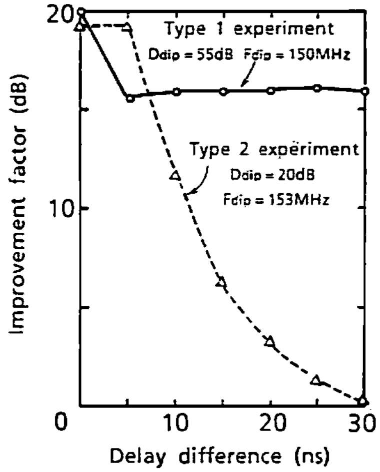

Fig. 3 Cancellation Improvement Factor versus Delay Difference

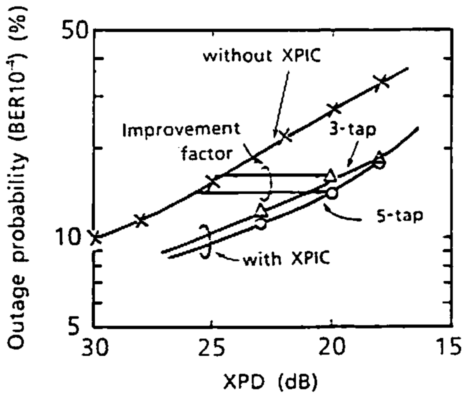

Fig. 4 Outage Probability at a BER 10^{-4} with XPD in Type 2 Experiment

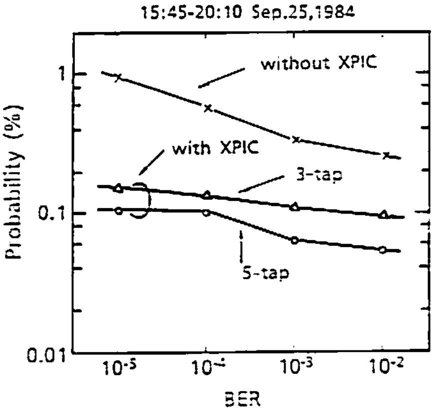

Fig. 5 Cumulative BER Distributions in Field Tests