Isolation Optimization of Radio Repeater System Based on Polarization Phase Control

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Abstract
Radio repeaters are widely used in the cellular phone system. To increase the gain of a repeater, it is necessary to ensure isolation between the service and donor antennas. This paper presents a method to optimize the isolation by controlling the phase difference between polarized waves in a sub-band.

Keywords: Radio Repeater  Polarized wave  Isolation

1. Introduction
Radio repeaters are widely used in the cellular phone system to improve signal quality in low-signal areas at a relatively low cost. Increasing the gain of a repeater may also be necessary to increase service coverage. Thus, it is necessary to ensure adequate isolation between the service and donor antennas to avoid signal problems that can arise from strong coupling between them. The degree of isolation between the service and donor antennas varies with the surrounding environment and the placement of the antennas. Practical repeater installation limitations often make it difficult to set up the antennas with the best isolation. This makes it necessary to control the gain of the repeater and to adjust the isolation between the service and donor antennas without changing the positions of the antennas. This paper proposes a novel phase control method for radio repeater systems. The proposed method improves the isolation between the service and donor antennas by adjusting the polarization of the waves in different parts of the bandwidth. Simulation results show that the proposed method improves the isolation performance by approximately 17 dB when a reflected path is fed into the repeater as loop interference.

2. Target of this work
Several methods have been proposed to improve the isolation between the service and donor antennas of radio repeaters. One method focuses on improving the ratio of the antenna back lobe and side lobe suppression [1]. Another method changes the polarization of the antennas to improve isolation [2]. The effect on isolation of changing the relative positions of antennas and reflectors was reported in Ref [3]. In the technique that changes the polarization of the antennas as (Ref [2]), it is necessary to optimize the phase when orthogonal polarization deteriorates. Therefore, we focused our attention on compensating for the orthogonal polarization between service and donor antennas and developed the device shown in Figure 1. This device is intended for a repeater that is connected to two ports of the dividers for each donor antenna and service antenna, with two orthogonal polarization ports. The device optimizes the phase between the vertical polarization and the horizontal polarization for the phase controller device which insert between the two ports of the divider and one orthogonal polarization port on the service antenna. Figure 2 shows the results of experiments in an anechoic chamber using this device. These experimental results show that isolation performance is improved by calculating the optimal phase (240 degrees) for the phase control device. However, it is obvious that the isolation performance has a frequency response in general. Therefore, if the optimum phase relationship needed to improve the isolation is different between uplink and downlink, the phase control device cannot simultaneously optimize the isolation.
in both the uplink and the downlink. In order to improve the isolation that minimizes the effect of
the frequency response, we propose a new method to select the optimal phase for each sub-band of
the uplink and the downlink bands as shown in Figure 3. In this paper, Chapter 3 describes the
simulation model for evaluating the effectiveness of the proposed method, and Chapter 4 presents
the simulation results.

3. Simulation Model

Figure 4 shows a simulation environment in which the donor and service antennas are
planar antennas with vertical-horizontal polarization. The donor antenna is right-handed circularly
polarized wave and the service antenna is left-handed circularly polarized wave so that the
incoming and outgoing signal waves should be orthogonal. Antenna directionality is used to model
three-dimensional patterns to increase the simulation accuracy. Specifications of the simulation are
summarized in Table 1. The vertical separation of donor and service antennas is 3 meters and the
horizontal separation angle is 180 degrees. Frequency is assumed to be 800 MHz and the
bandwidths of the uplink and the downlink are both set to 5 MHz. Figure 5 shows the propagation
model used to calculate the isolation between donor and service antennas. The propagation model is
composed of direct and reflected waves. The distance between the service antenna and a reflector is
24 meters. Here, the direct wave takes three factors into account. One is the propagation loss due to
the distance between service and donor antennas, the second is the loss of antenna directionality as
calculated by the relative position of the antennas and the third involves the degradation of the
orthogonal polarization. The reflected wave calculation includes the delay and phase rotation caused
by the reflector, adding in the effects of the direct wave.

4. Simulation Results

Figure 6 shows the characteristics and improvement of the isolation with phase control
between vertical polarization and horizontal polarization of the service antenna. The bandwidth for
phase control is divided from 10 MHz to 0.3 MHz. The initial value (Init) indicates the amount of
isolation when the phase control is not activated. We define the amount of isolation as the minimum
value of the uplink or downlink. The solid line shows the isolation performance itself, and the
dotted line indicates the improvement of isolation for each sub-band. In this figure, the
improvement of isolation is 7 dB when identical phase control is applied to the 10 MHz band of the
uplink and downlink (i.e. conventional method). However, the isolation improvement increases to
14 dB when individual phase control is applied to the uplink and the downlink. Moreover, it was
confirmed that the improvement of isolation increases by up to 17 dB with the optimal phase
selected for each divided sub-band, where the effects of frequency response are minimized. We
conclude that the proposed method can increase the improvement of isolation by up to 10 dB more
than the conventional method.

5. Conclusion

We have proposed a novel method to optimize isolation in radio repeater system, based on
phase control between polarized incoming and outgoing waves, and developed a simulation model
to evaluate its effectiveness. We conclude that isolation can be greatly increased by selecting the
optimal phase for each band, once divided into sub-bands.
References


Figure 1: Configuration of conventional method

Figure 2: Frequency versus isolation with phase control

Figure 3: Frequency versus isolation with phase control in each sub-band.
\(\phi_1-\phi_6\): Optimal phase for each sub-band
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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<tbody>
<tr>
<td>Frequency [MHz]</td>
<td>815~875</td>
</tr>
<tr>
<td>Uplink [MHz]</td>
<td>825~830</td>
</tr>
<tr>
<td>Downlink [MHz]</td>
<td>870~880</td>
</tr>
<tr>
<td>Vertical distance [m]</td>
<td>3</td>
</tr>
<tr>
<td>Horizontal distance [m]</td>
<td>0.6</td>
</tr>
<tr>
<td>Horizontal elongation [deg]</td>
<td>180</td>
</tr>
<tr>
<td>Distance of reflector [m]</td>
<td>24</td>
</tr>
</tbody>
</table>

Table1: Specifications of the simulation

![Diagram](image)

1: (\(E_\phi, E_\theta\))e^{i\omega t}e^{-\alpha d} \times \text{Factor}

2: (\(E_\phi, E_\theta\))| \(\Gamma\) | e^{j\omega(t+\Delta t)}e^{-\alpha L} \times \text{Factor}

Isolation = 1 + 2

\(\Gamma\) Antenna directionality loss
\(e^{-\alpha d}\) Propagation Loss
\(\text{Factor}\) Degradation of the orthogonal polarization
\(e^{j\omega(t+\Delta t)}\) Delay and phase rotation

Figure4: Simulation Environment

Figure5: Simulation Model

Figure6: Improving isolation by selecting the optimal phase for each sub-band.