ADAPTIVE ARRAY ANTENNA TECHNOLOGY FOR CO-CHANNEL INTERFERENCE CANCELLATION OF CDMA OPEN AREA REPEATER SYSTEM

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Abstract

This paper proposes a new idea to realize an open area repeater (OAR) with low cost and easy installable and manageable characteristics by adding array antenna technology to traditional direct repeater (TDR). TDR is inexpensive but has a problem related to co-channel interference between transmitter and receiver antennas. This co-channel interference leads to a long separation between antennas. The proposed method is as follow: First, we can reduce co-channel interference signal to a certain extent by a proper physical location between antennas. After that, by controlling side-lobe pattern of receiver antenna, we reduce the interference signal level to a certain extent. Finally, through the time-domain signal processing, we can let down the interference signal level below than the desired level. Simulation result shows the realization possibility of OAR with co-located antennas.

1. Introduction

The wireless infrastructure was composed of base-stations and repeaters. Even up to now, array technology has been mainly focused on the technical area connected with BS [1-3] such as smart antenna. In this paper, we deal with the array technology for repeater, especially OAR system. Main roles of repeater are to extend the cell coverage and remove small shadowing areas. Repeater is categorized closed area repeater (CAR) and OAR. Several kinds of present open area repeaters have some technical and operational problems of their own. Fiber-optic repeater is a good solution because it has no interference between repeater antennas, but its operational cost is very high because of expensive rent fee of exclusive fiber-optic line. Frequency-conversion repeater has no wired signal line, so its operational cost is proper. But, its frequency efficiency is not good because of frequency conversion between donor unit and service unit. As to TDR, its price is very inexpensive, but it has a technical problem like the co-channel interference. This co-channel interference leads to a long separation between antennas. Table 1 shows an example demonstrating the problem of antenna tower when TDR system setting up.

Table 1. Physical separation between antennas of TDR (maximum EIRP of Subscriber Bottom = 58dBm, maximum EIRP of Donor Bottom = 38dBm, and required minimum antenna isolation = 86dB) [4].

Vertical		Horizontal
Donor Top / Subscriber Bottom	Subscriber Top / Donor Bottom	
8.8m	7.8m	98m

If we can reduce this co-channel interference, the long separation between transmitter and receiver antennas will not be needed, and we will get the more cost effective repeater structure. This paper shows a systematic approach to realize a certain OAR with low cost and easy installable and manageable characteristics by adding a multidisciplinary array technology to TDR.

2. Systematic Approach

The problem we consider is co-channel interference between transmitter and receiver antennas of TDR. Fig. 1 shows the system configuration of TDR with array antenna and interference cancellation system (ICS).

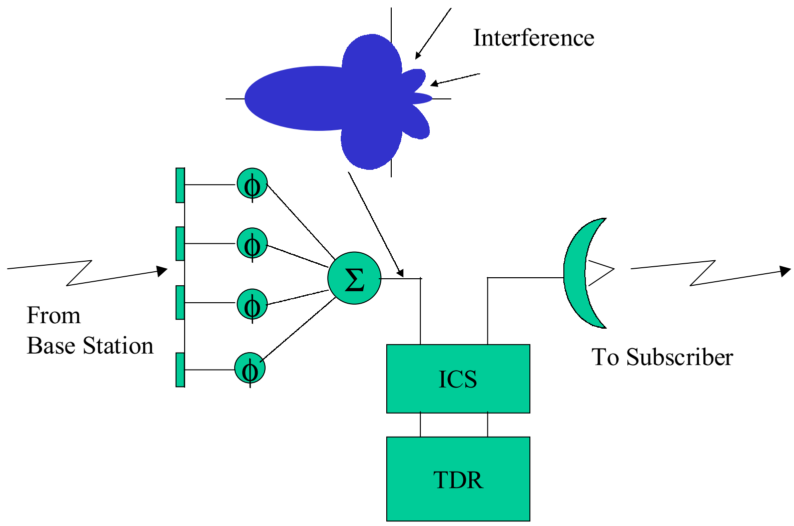


Fig. 1. System configuration of TDR with array antenna and ICS unit.

How to get a desired isolation ratio between donor antenna and subscriber one is as follow: First, co-channel interference can be reduced by a proper physical location of antennas. At this, the far low side-lobe technique is needed. Second, the interference signal coming to receiver can be reduced by controlling the side-lobe pattern of receiver antenna. Here, RF side-lobe cancellation (SLC) technique is required. Finally, through a proper time-domain signal processing, we can let down the interference signal level below than the desired level.

We start from an example of a CDMA TDR with its amplification gain = 80 to 100 dB. In this case, 110dB isolation ratio between transmitter and receiver is required. In order to obtain this isolation ratio, long separation between two antennas was needed. But, we can get 110dB isolation ratio without long separation between two antennas. First, 70dB isolation ratio can be obtained by a proper physical location (2~3m separation vertically) and patterns of transmitter and receiver antennas. Next, 20dB isolation ratio can be obtained by RF side-lobe cancellation circuit. Here, we have to consider that directions of interference signals can be changed by setting places of antenna tower and antenna towers themselves, and we also have to be careful so that main beam of antenna can maintain its original shape when RF side-lobe cancellation circuit operating. To do these works, we can use several useful pattern-synthesis techniques such as side-lobe pattern nulling technique. We have to remember that it is nearly impossible to get 90dB isolation ratio at only 2~3m separation distance between antennas without a proper SLC. Finally, 20dB isolation ratio can be obtained by the time-domain co-channel interference cancellation circuit. Fig. 2 shows the proposed time-domain co-channel interference cancellation circuit. In this circuit, the system bandwidth is determined. The higher cancellation ratio is, the narrower cancellation bandwidth is.

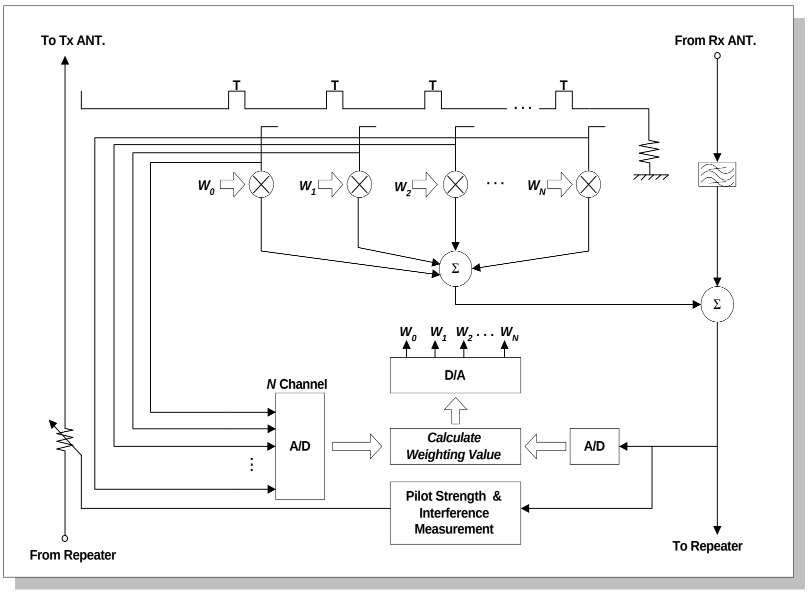
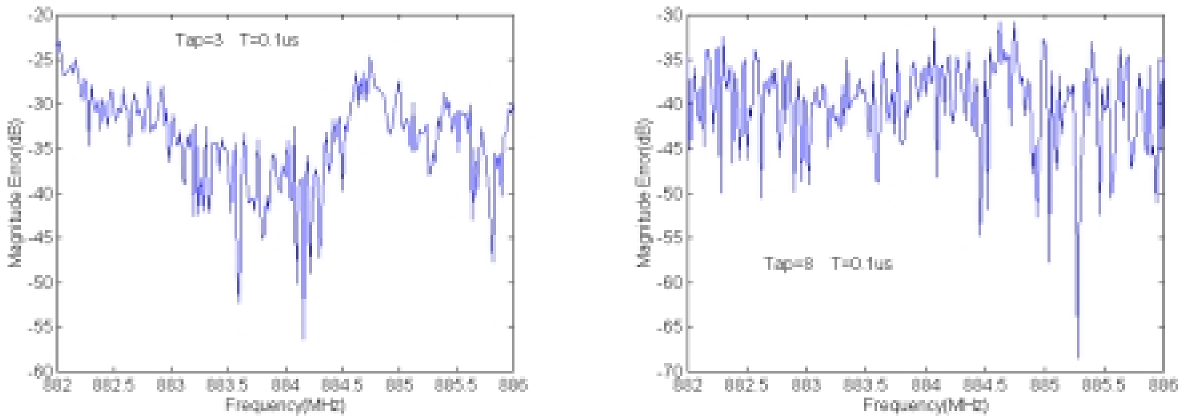


Fig. 2. Proposed time-domain co-channel interference cancellation circuit (T = delay. Wi = i-th weighting factor).

We measured magnitude and phase transfer functions between transmitter and receiver antennas at anechoic chamber using arbitrary two antennas, and calculated the weighting factors by least mean square error algorithm when number of tap-delay = 3 and 8. Here, the processing time doesn't matter because the channel characteristic between antennas is almost static. Those results are shown at Fig. 3. Fig. 3 explains the fact that 20dB isolation ratio can be obtained in the range of a desired bandwidth and the more number of taps, the better performance can be obtained because the accuracy of weighting factor estimation betters. Fig. 4 shows achievable interference cancellation ratio according to magnitude and phase error estimation.



(a) (b)

Fig. 3. Simulation results. (a) Number of tap=3, delay time T=0.1us. (b) Number of tap=8, delay time T=0.1us.

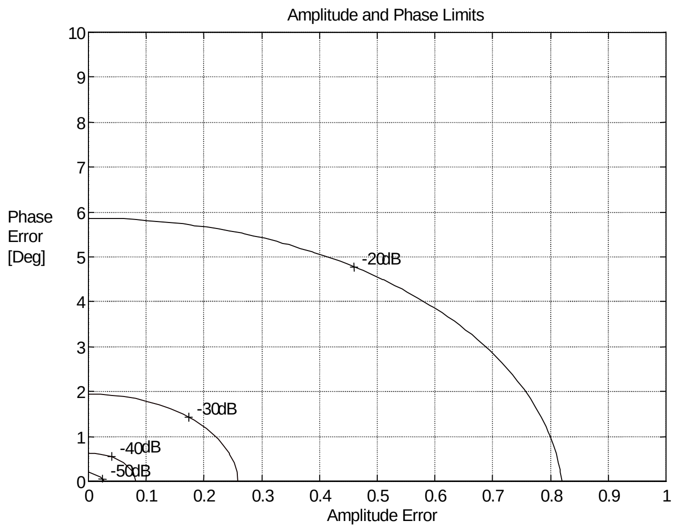


Fig. 4. Achievable interference cancellation ratio according to magnitude and phase estimation error.

3. Conclusion

This paper presents a new idea to realize an open area repeater with low cost and easy installable and manageable characteristics by adding array antenna technology to traditional direct repeater. This idea allows the realization possibility of more cost-effective open area repeater by co-locating antennas than other repeaters such as fiber-optic repeater and frequency-conversion repeater.

References

[1] SARG [Smart Antennas Research Group] website, http://www-isl.stanford.edu/groups/SARG/
[2] MPRG [Mobile & Portable Radio Research Group] website, http://www.mprg.ee.vt.edu/
[3] Theodore S. Rappaport, ed., Smart Antennas, IEEE, Inc., 1998.
[4] Home page of Repeater Technologies, Inc., http://www.repeaters.com/