*Proceedings of the 2017 Winter Simulation Conference*
*W. K. V. Chan, A. D'Ambrogio, G. Zacharewicz, N. Mustafee, G. Wainer, and E. Page, eds.*

# VIRTUAL TERRAIN NULLIFICATION USING PHASED ARRAY ANTENNAS

Vinay B. Ramakrishnaiah
Robert F. Kubichek
Suresh S. Muknahallipatna

Dept. of Electrical & Computer Engineering, University of Wyoming
1000 E. University Ave.
Laramie, WY, 82071, USA

## ABSTRACT

A novel method of Virtual Terrain Leveling (VTL) is proposed that virtually nullifies the effects of terrain on radio propagation using phased array antennas. This method has potential applications in avoiding interference in technologies like 5G, and ad hoc networks. Simulation results are provided to show the distribution of power for different terrains, and to highlight the benefits of using VTL.

## 1 INTRODUCTION

Unlike wired communication, wireless communication is sensitive to ambient noise as well as interference due to the use of a shared medium. The link quality is significantly affected by the surrounding terrain like buildings, hills, foliage, etc. Due to this, fixed infrastructures such as cell phone networks experience inter-cell interference, which is exacerbated by the introduction of heterogeneous overlaid networks like low power nodes and remote radio heads. Inter-cell interference is one of the key challenges that need to be overcome for the next generation of cell-phone infrastructure (5G). Terrain changes also pose a problem for communication and localization in mobile ad-hoc networks and in the deployment of Internet of things (IoT). Many of these problems can be addressed through careful antenna design, but these can be challenging as they require complex hardware and software. We propose the method of VTL that acts as a trade-off between the complex antenna design approaches and the simple omni-directional antennas.

## 2 VIRTUAL TERRAIN LEVELING METHODOLOGY

VTL nullifies the effects of terrain virtually at a certain distance from the transmitter by increasing the gain in the direction of increased path loss within a certain threshold. For a passive antenna, VTL directs the gain from directions with received power above a certain threshold to the directions with received power below a specified threshold. Overall, it tries to achieve a flat response in all directions up to a certain distance from the transmitter.

Power received at a certain distance from the transmitter can be approximated using a suitable path loss model like the Walfisch-Ikegami model (WIM) as

$$P_{rWIM}(\theta) = \frac{P_t G_t(\theta) G_r(\theta)}{Loss_{WIM}(\theta)},$$

where $G(\theta)$ represents the antenna gain at different look angles, and $P_t$ is the transmitter power.
Using omni-directional antennas for both the transmitter and receiver, the power received can be written as

$$P_{rWIM}(\theta) = \frac{P_t}{Loss_{WIM}(\theta)}.$$

978-1-5386-3428-8/17/$31.00 ©2017 IEEE 

Similarly, the received power in the case of free-space model (FSM) can also be calculated. VTL tries to find the transmitter antenna gain such that

$$\frac{P_t G_t(\theta)}{Loss_{WIM}(\theta)} = \frac{P_t}{Loss_{FSM}(\theta)}$$

or

$$G_t(\theta) = \frac{Loss_{WIM}(\theta)}{Loss_{FSM}(\theta)}. \tag{1}$$

As the path losses calculated using the WIM and the FSM vary due to the inherent model behavior, the transmitter gain obtained using VTL represents a transmitter with an unconstrained gain in all directions. The unconstrained gain may not be practically achievable using RF amplifiers or can be expensive. A practical approach would be the use of a passive antenna system whose output and input powers are equal. To achieve this, the Nelder-Mead (NM) simplex optimization and the convex (CVX) optimization approaches were used. Using NM method, an unconstrained search for different phases was performed that could be applied to the antenna phase shifters. In the CVX approach, a minimization of error between the ideal pattern and the estimated pattern was performed by constraining the amplitude of the weights to be less than or equal to one.

## 3 RESULTS AND ANALYSIS

The simulations were performed using Matlab by setting up the receiver at the intersection of 4 quadrants, where each quadrant had a different type of terrain, viz., open area, suburban area, mid-rise buildings, and high-rise buildings. The Walfisch-Ikegami propagation model was used to compute the path losses and the received power for a transmitter-receiver separation of 1000 m with the use of 36 antennae based VTL is shown in Fig. 1. We can see from Fig. 1 that VTL tries to push the gain in the directions of increased path loss even with passive antennas.

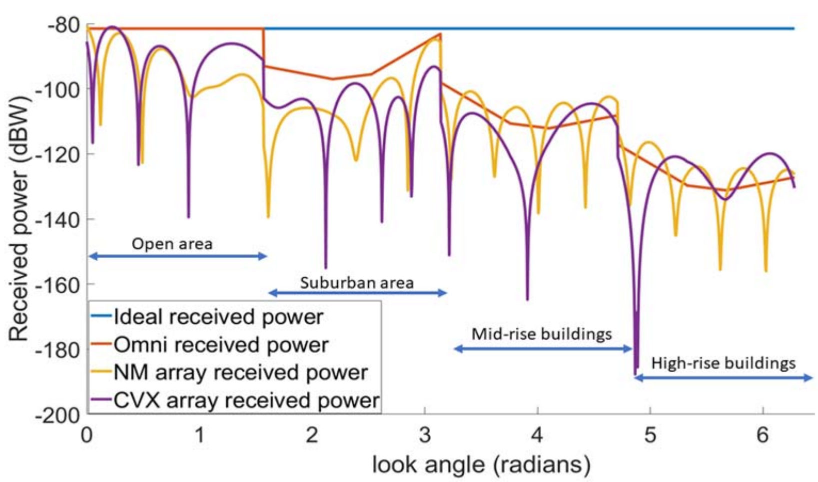


Figure 1: The received power computed using WIM, desired power using VTL, and the obtained power using passive antennas with limited degrees of freedom.

## 4 SUMMARY

The novel approach of VTL is proposed that uses phased array antennas to nullify the effects of terrain virtually. This approach can potentially solve issues like inter-cell interference in cell-phone networks, and also aids in the deployment of mobile ad hoc networks. Simulation results showed that VTL tries to increase the antenna gains in the directions of obstacles that increase path loss within a certain threshold. Tests were also conducted with different antenna array geometries with a varying number of antennas. Further, we want the test the performance of VTL applied to practical networks.