Extending the diversity outage performance of microwave LOS links to MIMO.

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Wireless microwave links over long range LOS links are currently being redeployed as many links installed at the end of the past century are at the end of their life cycle and as satellite coverage still experiences some economical or technical shortfalls. There are also many projects aimed at providing high speed internet to rural and remote areas best covered with microwaves links also contribute to this renewed interest. The use of MIMO OFDM(A) combined with adaptive modulation and coding as well as automated retransmission is a competitive and efficient technology for these scenarios.

Since the first 'Barnett' equation [1], improved to include diversity by Vigant [2] and many time further refined to the current ITU standards[3], we have used an outage probability model to predict the quality of service of microwave links. The outage probability is a function of frequency, climate, terrain, distance, inclination, antenna diversity and mostly system gain. In an adaptive context, this outage is not as clearly defined since a modification in received power induces a modulation, coding and even MIMO scheme (spatial multiplexing vs space-time coding) modification. In this paper, we use a Maximum Ratio Combining approach assuming an Alamouti type space-time coding.

We thus modify the empirical outage probability model to extend the diversity concept to a MIMO concept. This is readily possible by using the outage equations of doubly correlated Rician fading channels [1]. Essentially, one defines a Kronecker correlation structure of the MIMO transmission matrix H of dimension n by m (n receive and m transmit antennas)

$$H = R^{1/2} H_w S^{1/2}$$

where the elements of H are the channel gains for each antenna pair, Hw is an n by m diagonal matrix with independent Gaussian complex random variables of unit variance as diagonal elements, and R and S are the receive and transmit correlation matrices which have diagonal entries. The term doubly correlated refers to these two matrices. The first order approximation of the outage probability in [4], then can be written as, where n is greater than m:

$$F(\gamma) = \frac{(n-1)!}{(n+m-1)!\,|R|^n |S|^m} \left(\frac{\gamma}{\bar{\gamma}}\right)^{nm}$$

where γ is the threshold SNR and $\bar{\gamma}$ its mean, $|.|$ stands for the determinant operator and n can be replaced by m at the numerator if it is smaller than m. A relatively straightforward extension of the empirical outage probability can be derived by using a simple diversity case (n=2, m=1) and identifying the diversity improvement which includes a correlation factor. The improvement factor can be identified with the diversity improvement in [3]. By symmetry one can obtain both the transmit and receive correlation as a function of antenna separation and distance. Finally, one can adapt the ITU recommendation [3] in equations (99) to (106).

[1] Barnett, W. T. (1972). Multipath propagation at 4, 6, and 11 GHz. Bell Labs Technical Journal, 51(2), 321-361.
[2] Vigants, A. (1968). Space-diversity performance as a function of antenna separation. IEEE Transactions on Communication Technology, 16(6), 831-836.
[3] "ITU-R P.530-14", *Propagation Data and Prediction Methods Required for the Design of Terrestrial Line-of-Sight Systems*, 2012.
[4] Jin, S., McKay, M. R., Gao, X., & Collings, I. B. (2007). Asymptotic SER and outage probability of MIMO MRC in correlated fading. *IEEE Signal Processing Letters*, *14*(1), 9-12.