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Title: **On Channel Models for Evaluation of GMSK and 8PSK with Receive Diversity and Interference Cancellation**
Document for: **Discussion**

1. Introduction

Contributions to the GERAN evolution workshop and GERAN 25 have offered some initial proposals on the channel models and system simulations that should be used to evaluate the impact on system performance of mobile station receive diversity (MSRD). In these contributions, there seems to be some general agreement, though significant differences remain.

This contribution reviews the channel models in these proposals and makes some recommendations regarding the areas of disagreement.

2. GERAN Diversity Channel Models

The channel models proposed in contributions [1-7] all have several aspects in common:

i) the desired and interfering signals are assumed to fade independently of each other;

ii) with the exception of [3], it seems generally agreed that is reasonable to use a single correlation coefficient ρ for all signal sources, though it is recognized in [1-3] that these correlation coefficients are generally not the same given the differing angles of departure and arrival associated with each signal sources.

iii) a gain imbalance exists between the primary and diversity antennas. While this imbalance has a significant impact on receiver sensitivity, it is not believed to have a significant impact in interference limited environments.

Contributions [3] and [6] introduce two additional aspects to the channel model:

iv) a noise figure imbalance between the primary and diversity antennas

v) a change to the distribution of the phase difference between the primary and diversity antennas for each signal source.

In contribution [6], a phase shift is added to the diversity branch, and the phase shift is chosen randomly for each burst. Though not explicitly stated, it seems clear that this phase shift is chosen independently for each burst and for each signal source. Similarly, in [3], it is noted that "different AoD/AoA's will introduce different phase shifts on each diversity branch." The meaning of this statement is somewhat unclear in that different phase shifts will always result if the desired and interfering sources are assumed to fade independently. Presumably, the intention was to note that the distribution of the phase difference is different for each signal source, since this is a consequence of the spatial channel model (SCM) [8], the use of which is advocated in [3].

In choosing the simulation models and assumptions, it should be remembered that the cost impact of MSRD is not insignificant (unlike SAIC), and as a result, the benefits in coverage and capacity must be weighed against the increased cost. As a result, simplifications to the models should not overtly prejudice the results, either positively or negatively, so as to invalidate any cost-benefit analysis. In particular, assumptions concerning the antenna correlation and antenna gain and noise imbalances, which do not impact receiver performance in interference limited environments, should not excessively prejudice the evaluation of receiver sensitivity in noise limited environments. This is especially true in light of the fact

that a single mobile station can benefit from the better coverage and range resulting from improved receiver sensitivity, whereas an improvement in area-wide system capacity will not be observed without a significant market penetration of MSRD.

In the following, the issues raised in items (ii)-(v) above will be addressed further.

3. Gain Imbalance

It is generally well understood that an antenna gain imbalance has a significant impact on receiver sensitivity, and this has been illustrated in the simulation results presented in [2] and [7]. This impact on sensitivity is important because, as noted previously, receiver sensitivity directly affects range and coverage. With respect to interference limited scenarios, it has been argued in [1] that an antenna gain imbalance is not significant because "the signal-to-interference ratio at the diversity antenna is not affected since noise and interference are attenuated equally." This argument is supported by the simulation results presented in [2] for a desired GMSK signal in the presence of GMSK interference in an interference limited environment.

In summary, the following points can be made with respect to the issue of gain imbalance:

- all mobile stations will have a significant gain imbalance. Even if a mobile station (of reasonable size) could be designed and manufactured without a gain imbalance, hand shadowing would unavoidably introduce one;
- it is clear that gain imbalance has a significant impact on receiver sensitivity, and thus can reduce the benefits of MSRD with respect to range and coverage. Since these are the only benefits achievable with an initially low market penetration, they should not be overestimated.

As a consequence, it seems clear that one or more non-zero gain imbalances should be agreed upon for the evaluation of MSRD.

4. Noise Figure Imbalance

The channel models in [3,6] allow for the possibility of a noise imbalance, deriving from differences in the noise figures of the primary and diversity receivers. Though it is unlikely that the two noise figures will be precisely the same, the difference between the two noise figures is likely to be less than the antenna gain imbalance, especially since the noise figure is not affected by the positioning of the hand relative to the phone.

A difference of *X* dB between the noise figures of the receivers for the primary and diversity antennas can be shown to be equivalent to an antenna gain imbalance of –*X* dB. Thus, a situation in which the primary and diversity antennas both have gain G, but the primary and diversity antennas have noise figures NF_1 and NF_2, is precisely equivalent to a situation in which the two noise figures are equal, but the antenna gains for the primary and diversity antenna are G and $G + NF_2 - NF_1$. This equivalence can be achieved by multiplying the baseband output of the diversity antenna receiver by $10^{((NF_1 - NF_2)/10)}$.

If a noise figure imbalance is ultimately included in the channel model, the difference between the noise figures of the primary and diversity antennas should be combined with the antenna gain imbalance to produce a single gain imbalance parameter. Thus, a system with primary and diversity antennas with gains G_1 and G_2 and noise figures NF_1 and NF_2 is equivalent to a system having a common noise figure of NF_1, and antenna gains of G_1 and $G_2 + NF_1 - NF_2$. The resulting effective gain imbalance is thus $G_1 - G_2 + NF_2 - NF_1$

5. Random Phase on the Diversity Antenna

The comment in [3] that "different AoD/AoA's will introduce different phase shifts on each diversity branch," was presumably intended to note that the distribution of the phase difference on the primary and

diversity antennas is a function of the fading correlation parameter ρ, and that each signal source will see a different antenna correlation ρ if the SCM is used. If the same correlation parameter ρ is used for every signal source, the distribution of the phase difference on the diversity antenna will be the same for all users, though the instantaneous phase differences will not. A consequence of the spatial channel model advocated in [3] is that the parameter ρ depends on the location, antenna orientation, and antenna pattern of both the mobile station and the signal source of interest, and as a result, ρ will be different for every signal source.

In [6], it was suggested that a phase shift be added to the diversity branch, where the phase shift is chosen independently on $[0, 2\pi)$ for each burst and for each signal source. The effect of this random phase shift is to remove the correlation between the complex fading processes observed at the output of the primary and diversity antennas for each desired or interfering signal. However it should be noted that the amplitudes of the two fading processes are still correlated, and that this correlation is unchanged by the introduction of the random phase.

The net effect of the random phase shift introduced in [6] is that the set of phase differences between the desired and interfering signals seen at the output of the diversity antenna are independent of the set of phase differences seen at the output of the primary antenna. Without the introduction of the random phase shift, the set of phase differences between the desired and interfering signals seen at the output of the primary and diversity antennas are correlated, with the degree of correlation increasing with the magnitude of the correlation coefficient ρ. In the degenerate case in which the correlation coefficient ρ is equal to 1, the set of phase differences seen at the output of the primary and diversity antennas are exactly the same.

Given the complexity associated the calculation of the correlation coefficients for each source of a desired or interfering signal as well as the need to generate link curves for all combinations of correlation coefficients for the desired and interfering users, the use of the SCM is not preferred. The approach in [6] can be easily implemented and does not affect the simulation effort given that there are no parameters to vary. However, there is currently no evidence that this would improve the overall accuracy of the model.

6. The Spatial Channel Model

The use of the SCM [8] was advocated in [3]. However, it should be remembered that the spatial channel model was developed to evaluate and differentiate between candidate MIMO systems, and not for the simple case of two-antenna receive diversity. As a result, even when the SCM is used to model simple receive diversity, much of the overhead needed to evaluate and compare MIMO systems is still incurred. Specifically, in a system simulation, all of the following must be specified before the antenna correlation at the mobile station can be computed for a given signal source:

- the locations of the signal source and the mobile station
- the antenna orientations of the signal source and the mobile station
- the antenna patterns for the signal source and the mobile station

As a result, every signal source will yield a different correlation parameter. If link simulations were required to model multiple interferers in addition to the signal of interest, it would then be necessary to simulate all possible combinations of correlation parameters for the desired and interfering signals. Such an effort is not warranted given that the antenna correlation has been shown to have only a small impact on either the receiver sensitivity or on the performance of the receiver in interference limited environments.

7. Conclusions

In general, it is best if any simplifications of the link and system models made in order to reduce the simulation effort do not excessively bias the results, either positively or negatively, given that there is significant cost associated MSRD. Thus, known receiver impairments should be included in the models if they do not excessively complicate the simulation effort. In particular, reasonable estimates of antenna gain imbalance, antenna correlation, and noise figure imbalance should be included in the models. The noise figure imbalance can be combined with the antenna gain imbalance as described in Section 4.

Given that there is currently no evidence that the random phase shift described in [6] will improve the accuracy of the link model, it should not be included at this time.

8. References

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[4] Nokia, AHGEV-002, "MS Rx Diversity", 3GPP GERAN Evolution Ad Hoc, Copenhagen, Denmark, 1819 May 2005

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[7] Motorola, AHGEV-021, "Mobile Station Receive Diversity Considerations", 3GPP GERAN Evolution Ad Hoc, Copenhagen, Denmark, 18-19 May 2005

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