

Source: Motorola
Title: System Capacity of Mobile Station Receive Diversity With DARP
Document for: Discussion

1. Introduction

The GERAN Evolution Workshop [1][2][3][4] initiated discussion on adding Mobile Station Receive Diversity (MSRD) to improve the forward link performance of GSM/GPRS/EDGE. Link performance of DARP with MSRD with antenna impairments has been presented in [4][6]. System capacity has been discussed, but there have been questions as to what channel models and impairments should be used. Some have proposed the use of a single value for antenna correlation, some the use of a different antenna correlation value for each handset-site link, and one proposed [7] the use of the 3GPP spatial channel model (SCM) [8]. In this contribution we will present capacity results using a single value of antenna correlation.

In GERAN 25, we showed a candidate methodology [5] which could be used for system simulations of DARP with MSRD. The issue is to find a link-to-system mapping which is sufficiently accurate to predict system capacity, including the effects of various degradations, and yet does not require an inordinate amount of processing time, as would be the case with embedding link simulations into system simulations. When MSRD is added to DARP, the number of input variables increases, and we cannot anticipate that any may be ignored. In this contribution, we discuss the mapping details, present the system simulator for DARP+MSRD, and show system voice capacity results.

A validation process was used on the link simulator mapping to ensure that the degradation due to mapping was small. This contribution discusses the validation process and presents results.

Finally, system voice capacity results are shown with the described link-to-system mapping methodology, and with and without realizable values of antenna gain imbalance and antenna correlation.

2. Link-to-System Mapping

The link-to-system mapping was validated by comparing the actual link simulator to a “mapped link simulator”. The “mapped link simulator” read the desired and interfering signal levels from the actual link simulator on every burst and translated them to estimated BEP and FEP with the stage-1 and stage-2 maps. The actual and estimated FER for one antenna are shown in Figure 1. The degradation from the mapping process is considered negligible.

For two antennas, we showed in [5] that maximal ratio combining (MRC) and Single Antenna Interference Cancellation (SAIC) could be used as a conservative estimate of the performance of Dual Antenna Interference Cancellation (DAIC). In this method, the MRC branch gains were determined and applied to the desired and interfering signals. The CIR and DIR were calculated from the resulting summed branches, and then used to estimate BEP and FEP through the stage-1 and stage-2 maps derived from non-diversity link simulations.

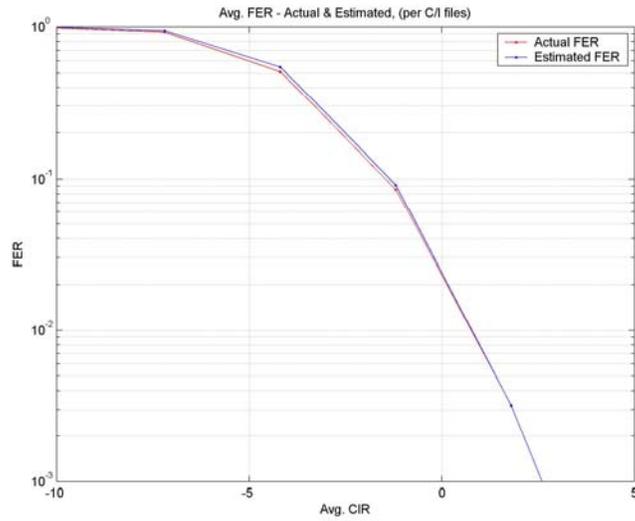


Figure 1 – Actual and estimated link FER for one antenna

3. System Performance

3.1. Reference System Scenarios

Table 1 shows the system assumptions and parameters.

Parameter	Value	Unit
Frequency	1900	MHz
Bandwidth	1.2	MHz
Reuse	1/1 (TCH)	-
Voice Codec	AMR 5.9 FR	-
Cell Radius	1000	m
Sectors (cells) per Site	3	-
Sector Antenna Pattern	UMTS 30.03	-
Propagation Model	UMTS 30.03	-
Log-Normal Fading: Standard Deviation	8	dB
Log-Normal Fading: Correlation Distance	110	m
Log-Normal Fading: Inter-Site Correlation	50	%

Adjacent Channel Interference Attenuation	18	dB
Handover Margin	3	dB
Antenna Gain Imbalance (AGI)	0 or 2.0	dB
Antenna Correlation (ρ)	0 or 0.4	-
Fast Fading	Flat or TU	-
Mobile Speed	3 or 50	km/hr
Hopping	Ideal FH, Random RF	-

Table 1. System Assumptions and Parameters

3.2. System Capacity Results

The system voice capacity is Effective Frequency Load (EFL) at which 95% of the calls have less than 2% FER over the call duration. Blocked calls are counted against the call satisfaction statistics.

Figure 2 and Figure 3 show the system capacity at 3 km/hr and 50 km/hr, respectively. Both figures show the conventional receiver (CR), 1-antenna DARP, or DARP+MSRD. The DARP+MSRD receiver is shown with or without the combined antenna impairments of 2 dB antenna gain imbalance (AGI) and an antenna correlation of 0.4. The antenna correlation is the magnitude of the complex correlation. Note that the curves with DARP+MSRD use the MRC+SAIC conservative approximation to dual antenna interference cancellation, as presented in [5]. Table 2 contains a summary of the performance curves at the 95%-ile point, which is defined as the system capacity.

With only one antenna, the channel model has quite a significant effect, the TU channel being much more benign than flat fading. With DARP+MSRD, TU is slightly better than flat fading. Both MSRD and the TU channel tend to reduce the deep nulls experienced in flat fading.

The effects of antenna gain imbalance and correlation are shown together, and only compared to the case of no impairments with flat fading. The degradation is insignificant, which is consistent with previous link simulations [5][6] that showed a smaller impact to interference-limited situations than noise -limited situations.

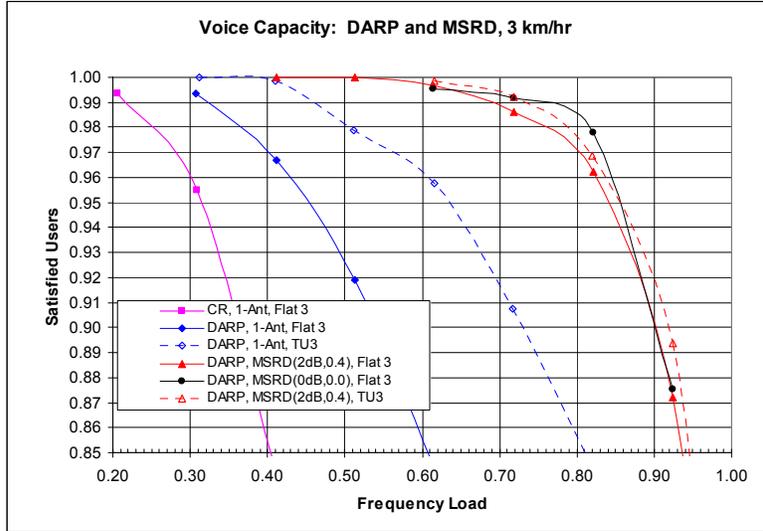


Figure 2 – Voice system capacity with DARP and MSRD, 3 km/hr

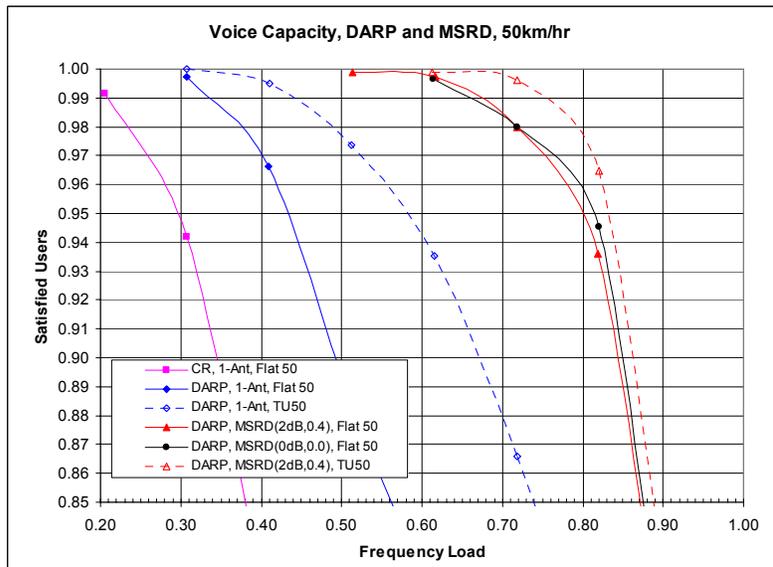


Figure 3 – Voice system capacity with DARP and MSRD, 50 km/hr

	Conventional Receiver	DARP	DARP+MSRD (2 dB AGI, 0.4 ρ)	DARP+MSRD (0 dB AGI, 0 ρ)
Flat, 3 km/hr	32%	45%	84%	85%
Flat, 50 km/hr	30%	42%	80%	82%
TU, 3 km/hr	-	64%	84%	-
TU, 50 km/hr	-	58%	83%	-

Table 2. System voice capacity (EFL for 95% <2% FER)

4. More Complex Correlation Models

Unique per-link antenna correlation models and the spatial channel model have been suggested for system simulations. Though we have not implemented those models to determine their impact, the insignificant effect of using 2 dB AGI and 0.4 correlation suggests that the more complex models may not have a major impact on the system capacity.

5. Conclusions

Mobile Station Receive Diversity (MSRD) increases the system voice capacity of a DARP receiver by a factor of 1.3-1.43X in TU fading, even with reasonable values of antenna gain imbalance and correlation. The corresponding gain is 1.75-1.9X in flat fading. Note that the MSRD gain is largest where it is most needed, in flat fading.

These system capacity gains assumed 100% penetration of the DARP or DARP+MSRD feature. If the penetration is lower, the full capacity gains will not be realized. However, another perspective is that at the same system loading, the addition of MSRD to DARP greatly increases the call satisfaction, the fraction of voice calls with less than 2% FER. For example, in Figure 2, at 45% EFL the 95% of the calls are satisfactory, but with DARP+MSRD, ~100% are satisfactory. A single user with DARP+MSRD will experience improved call quality.

The MSRD gains presented were the result of simulations on the forward TCH only. While diversity may be applied to the forward control channels as well, that benefit has not been simulated. Finally, the MSRD capacity gains are forward link only, and corresponding reverse link improvements may be needed for the operator to realize system gains.

In GERAN 25, we said,

There has been consensus amongst the contributions offered so far to GERAN concerning the potential link-level performance of MSRD. As next steps this contribution suggests that GERAN:

- a) establish clearly the network-level benefits of MSRD, including identification of appropriate link-system mappings for the GMSK-GMSK voice service cases already dealt with in the DARP FS.
- b) work to identify the necessary reference system scenarios, traffic models and radio resource configurations to permit the construction of heterogeneous or 'mixed' modulation interference scenarios. This will require input from system operators, but should leverage the work of the DARP FS to the greatest possible extent.
- c) commence work on identifying performance requirements for the reference GMSK-only test configurations already identified by the DARP WI and embedded in TS 45.005 and TS 51.010, *in parallel* with items a) and b).

With this contribution addressing item (a), we should now focus efforts on (b) and (c).

6. References

- [1] Nokia, AHGEV-002, “MS Rx Diversity”, 3GPP GERAN Evolution Ad Hoc, Copenhagen, Denmark, 18-19 May 2005
- [2] Ericsson, AHGEV-013, “Dual-Antenna terminals – Evaluation Principles and Scenarios”, 3GPP GERAN Evolution Ad Hoc, Copenhagen, Denmark, 18-19 May 2005
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- [4] Motorola, AHGEV-021, “Mobile Station Receive Diversity Considerations”, 3GPP GERAN Evolution Ad Hoc, Copenhagen, Denmark, 18-19 May 2005
- [5] Motorola, GP-051504, “Observations on Receive Diversity Implementation and Performance”, 3GPP TSG GERAN #25, Montreal, Canada, 20-24 June 2005
- [6] Nokia, GP-051459, “Proposed text on MS Diversity for the GERAN evolution feasibility study”, 3GPP TSG GERAN #25, Montreal, Canada, 20-24 June 2005
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- [8] 3GPP TR 25.996v6.1.0 (2003-09), “Spatial Channel Model for Multiple Input Multiple Output (MIMO) Simulation (Release 6)”