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Source: Cingular

Interference Characterization for SAIC Link Level Evaluation

1. Introduction

At the TSG-GERAN SAIC workshop on 8-9 January, 2003, and at the GERAN #13 meeting, configuration scenarios and system simulation parameters were decided for characterizing the interference environment for SAIC link level simulations [1]. This contribution presents results and recommendations for the interference characteristics for configuration scenario 3 proposed in [1].

This document is organized as follows. Section 2 presents some terminology definitions, Section 3 presents the simulation methodology and model assumptions, Section 4 presents characteristics of the interference environment for configuration scenario 3, and Section 5 gives recommendations regarding the interference environment for SAIC link level simulations.

2. Terminology

For the hopping TCH layer the Frequency Load (FL) is defined as the number of Erlangs supported in a cell divided by the total number of hopping time slots in the cell. This constitutes the total hopping space in that cell. Hence assuming that all 8 time slots are available to voice service, FL is defined as,

$$FL = \frac{Erlangs}{8 * HoppingFrequencies}$$

The *DIR* or Dominant to rest of Interference Ratio is defined as the ratio of the power, I_d, of the strongest interferer over the summation of the powers, I_k, of all the other interferers (co-channel as well as adjacent channel) as defined below. Note that I_d could be either a co-channel or an adjacent channel interferer.

$$DIR = \frac{I_d}{\sum_k I_k - I_d}$$

DIR_2 or second dominant to rest of interference ratio is defined as the ratio of the power, I_{d2}, of the second strongest interferer over the summation of the power, I_k, of all the remaining interferers (co-channel as well as adjacent channel), excluding the power of the strongest dominant interferer, I_d as defined below. Note that I_{d2} could be either a co-channel or an adjacent channel interferer.

$$DIR_2 = \frac{I_{d2}}{\sum_k I_k - I_d - I_{d2}}$$

The signal to interference ratio *CIR* is defined as the ratio of the power, *C*, of the desired signal over the summation of the powers, I_k, of all the interferers (co-channel as well as adjacent channel) as defined below.

$$CIR = \frac{C}{\sum_k I_k}$$

If the power of the *k*th co-channel interferer is denoted by the term I_{cck} and the power of the *k*th adjacent channel interferer is denoted by the term I_{ack} then the above given *CIR* definition can be re-written as

$$CIR = \frac{C}{\sum_k I_{cck} + \sum_k I_{ack}}.$$

The summation $\sum_k I_{cck} + \sum_k I_{ack}$ can also be denoted by the term I_{tot}. When attempting to characterize the interference environment for SAIC, it is important to study statistics of the individual interference contributions from each of the co-channel and adjacent channel interferers. The signal to interference ratio with respect to the *k*th co-channel interferer is denoted as CIR_{cck} and is defined as

$$CIR_{cck} = \frac{C}{I_{cck}}.$$

Similarly, the signal to interference ratio with respect to the *k*th adjacent channel interferer is denoted as CIR_{ack} and is defined as

$$CIR_{ack} = \frac{C}{I_{ack}}.$$

3. Simulation Model

For results presented in this contribution, the simulation parameters have been set according to configuration scenario 3 in [1]. Table 1 below shows the simulation model parameter settings used.

The system level simulation results presented in this contribution have been generated using a dynamic event-driven network level simulator that models a 1/1 reuse macro cell synchronized GSM network with cells laid out in an idealized cloverleaf or corner-excited pattern. 75 cells have been modeled in a rhomboidal pattern. Mobile stations are uniformly distributed across the simulation area and move in random directions. The simulator employs wrap-around to prevent end-effects.

The propagation model and antenna pattern proposed in UMTS 30.03 [2] have been used as agreed upon in GERAN. Two tiers of co-channel and adjacent channel interferers have been considered in the characterization of the interference environment. The network simulator currently does not model Rayleigh fading at a burst level. This is planned in a future upgrade to the simulator. The effect of inter and intra site cross correlation has not been included based on the conclusion in [3] that this correlation has a minor impact on the interference environment.

Table 1. Simulation Parameters

Parameter	**Value**
Reuse pattern	1/1
Spectrum	2.4 MHz (hopping layer only)
Carriers	12
System timing	Synchronous system
Frequency hopping	Synthesized random hopping with MAIO management
Cell layout	Cloverleaf pattern (corner-excited cells)
Sectors per site	3
Propagation model	UMTS 30.03 (120.9 + 37.6 $\log_{10}$d @ 900 MHz)
Propagation frequency	900 MHz
Log normal fading STD	6 dB @ 900 Mhz
Correlation distance	110 m
Adjacent channel interference attenuation	18 dB
BTS output power	20 Watts or 43 dBm
Minimum coupling loss	80 dB
Antenna pattern	UMTS 30.03
Cell radius	0.75 km @ 900 MHz
Tiers of interferers	2
Wrap around	ON
Channel profile	TU3
MS speed	3 km/h
Mean call duration	90 seconds
Minimum call duration	5 seconds
Handover margin	3 dB
DTX voice activity factor	0.6
Downlink power control	RXLEV + RXQUAL based with 14 dB dynamic range and 2 dB step size
Call dropping algorithm	RXQUAL based leaky-bucket type algorithm – Turned OFF when collecting *DIR* and DIR_2 statistics
Handover algorithm	RXLEV and RXQUAL trigger based algorithm
Inter and intra site lognormal correlation	Not modeled

4. Interference Characterization Results

This section presents results that characterize the interference environment for configuration scenario 3 for 25%, 40%, and 70% frequency loads. The first set of interesting results is regarding burst level *CIR* statistics with and without the effect of adjacent channel interference for the three frequency loads. Figures 1, 2, and 3 show the burst level *CIR* cumulative distribution functions (cdfs) for 25%, 40%, and 70% fractional load, respectively for all values of *CIR*. It is evident from the plots that as the frequency load increases, the adjacent channel interference has a diminishing contribution to the overall *CIR* statistics. So much so that for 70% frequency load the contribution of adjacent channel interference is almost negligible compared to the contribution of the co-channel interference.

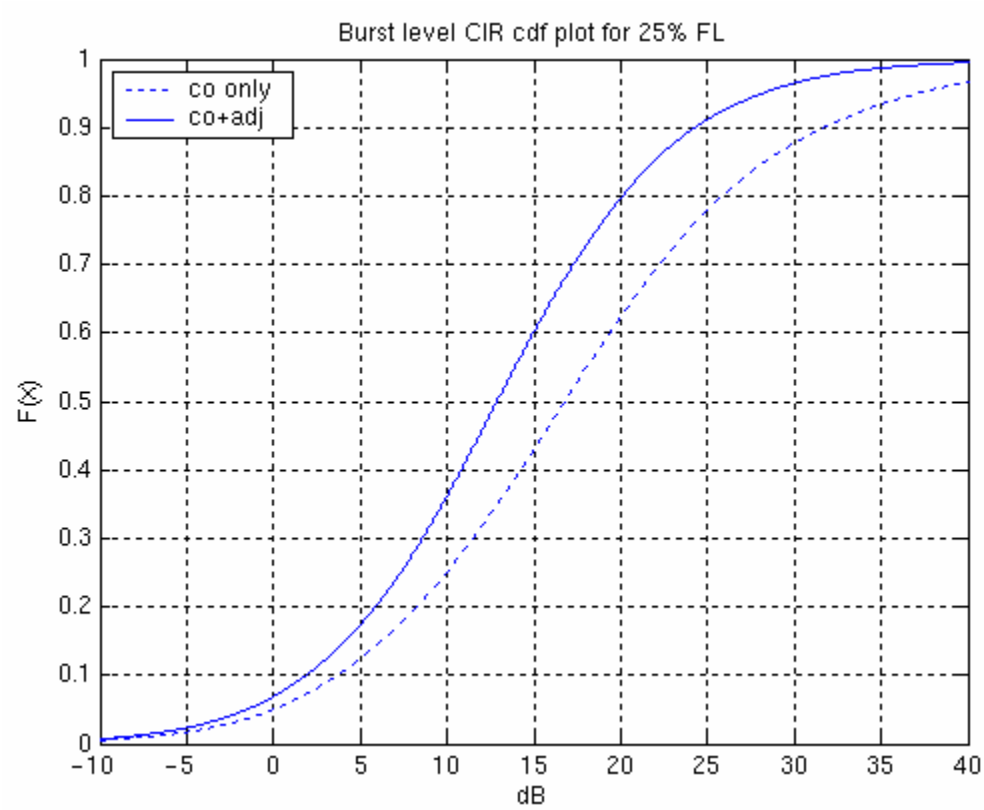

Figure 1: Burst level CIR CDFs for 25% FL w/ and w/o adj. channel interference

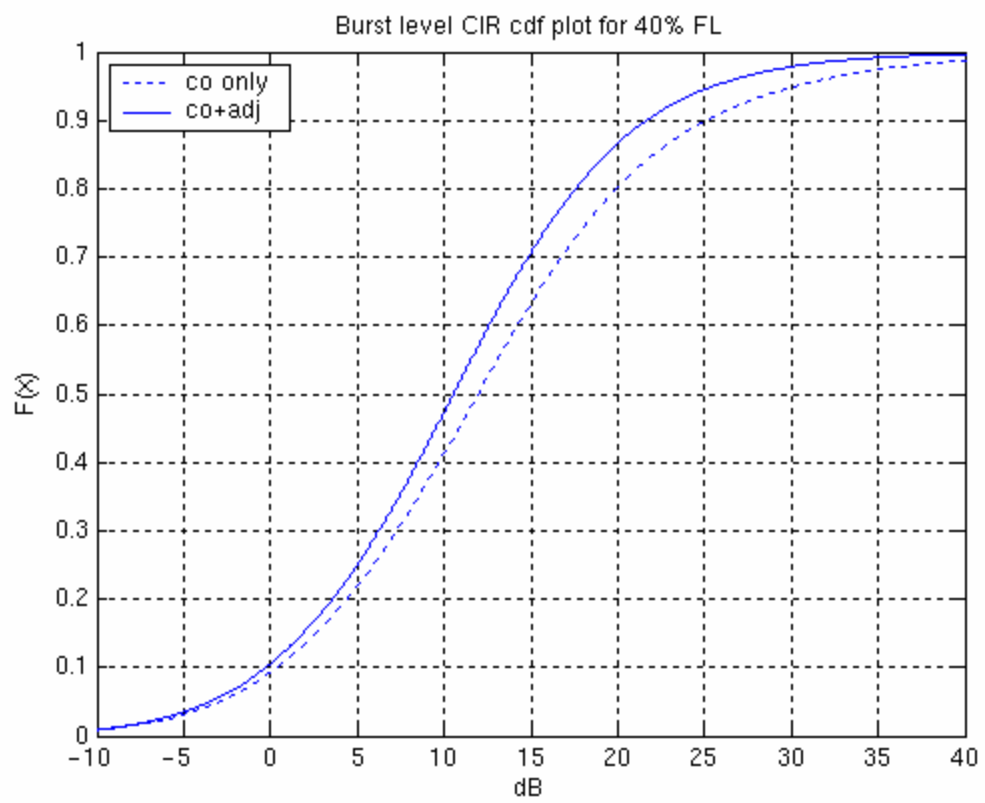

Figure 2: Burst level CIR CDFs for 40% FL w/ and w/o adj. channel interference

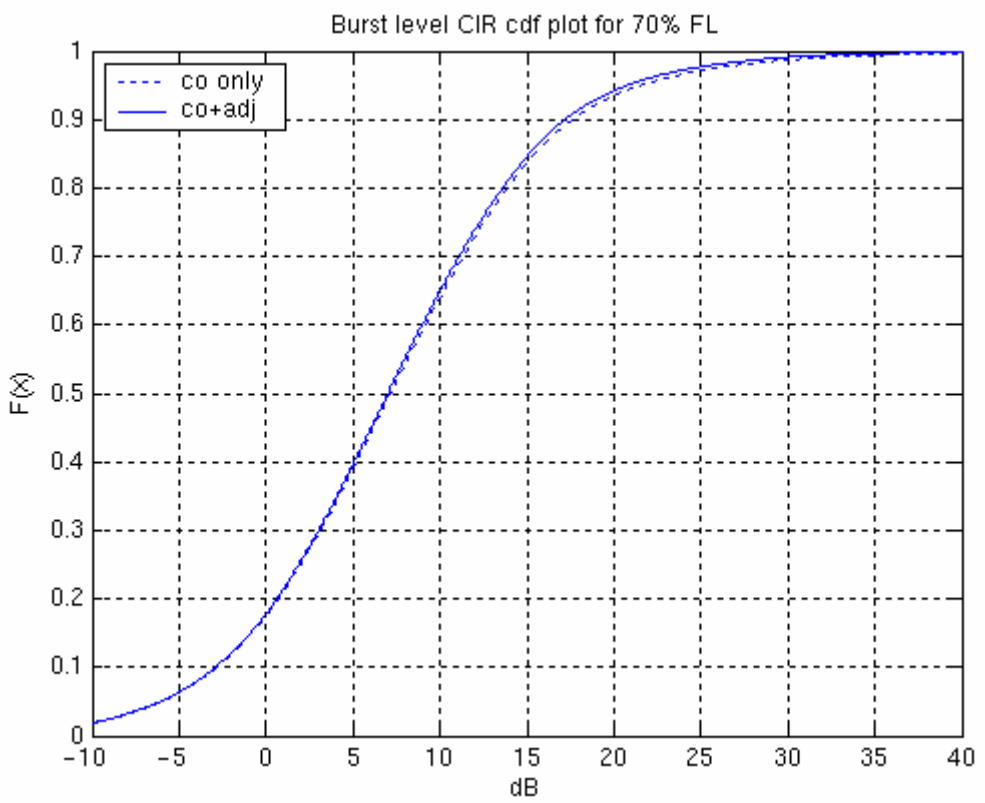

Figure 3: Burst level CIR CDFs for 70% FL w/ and w/o adj. channel interference

The second set of results is regarding *DIR* and DIR_2 statistics. Figures 4, 5, and 6 show *DIR* and DIR_2 cdfs for 25%, 40%, and 70% frequency loads respectively for those bursts that experienced *CIR*<10 dB. The interesting thing to note about these three set of curves is that the *DIR* and DIR_2 statistics are almost identical (differ significantly only above the 90th percentile) as the frequency load goes up from 25% to 70%. This is unlike the *DIR* and DIR_2 statistics shown in [4], which did not include the effect of adjacent channel interference. The results presented in Figures 4, 5, and 6 show that when adjacent channel interference is taken into account, the *DIR* and DIR_2 statistics remain fairly steady even when the frequency load changes by a large amount from 25% to 70%. This is encouraging because it indicates that the performance of SAIC algorithms that are sensitive to *DIR* statistics will likely not degrade as the system load goes up.

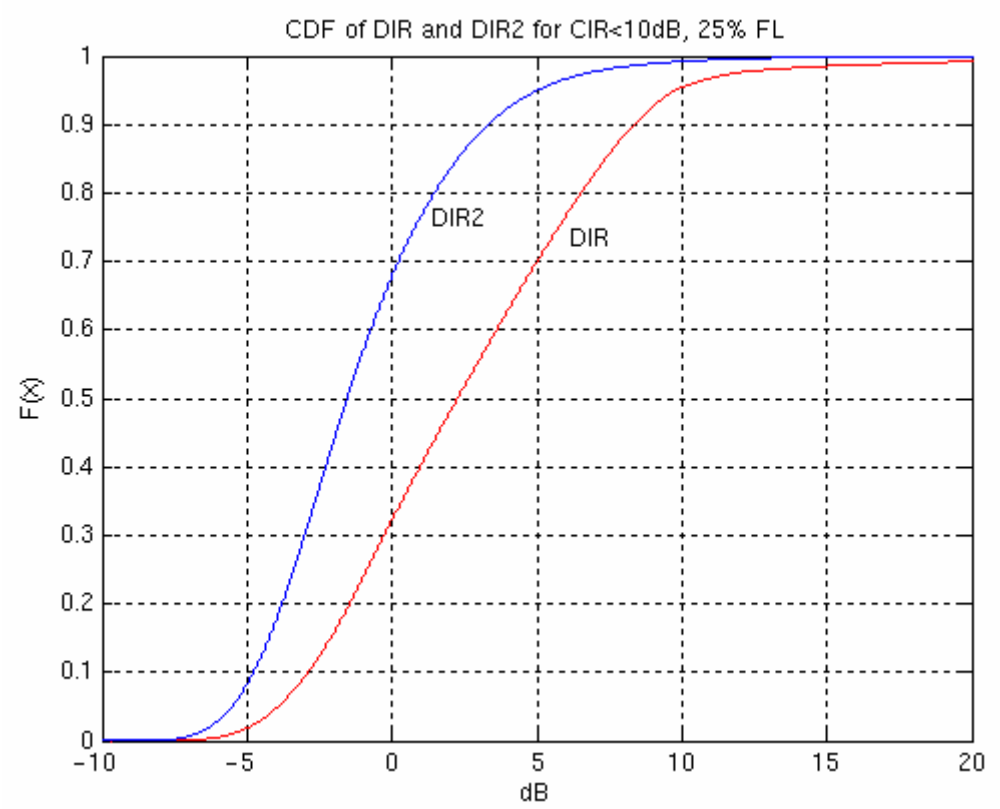

Figure 4: *DIR* and DIR_2 cdfs for *CIR*<10 dB and 25% FL

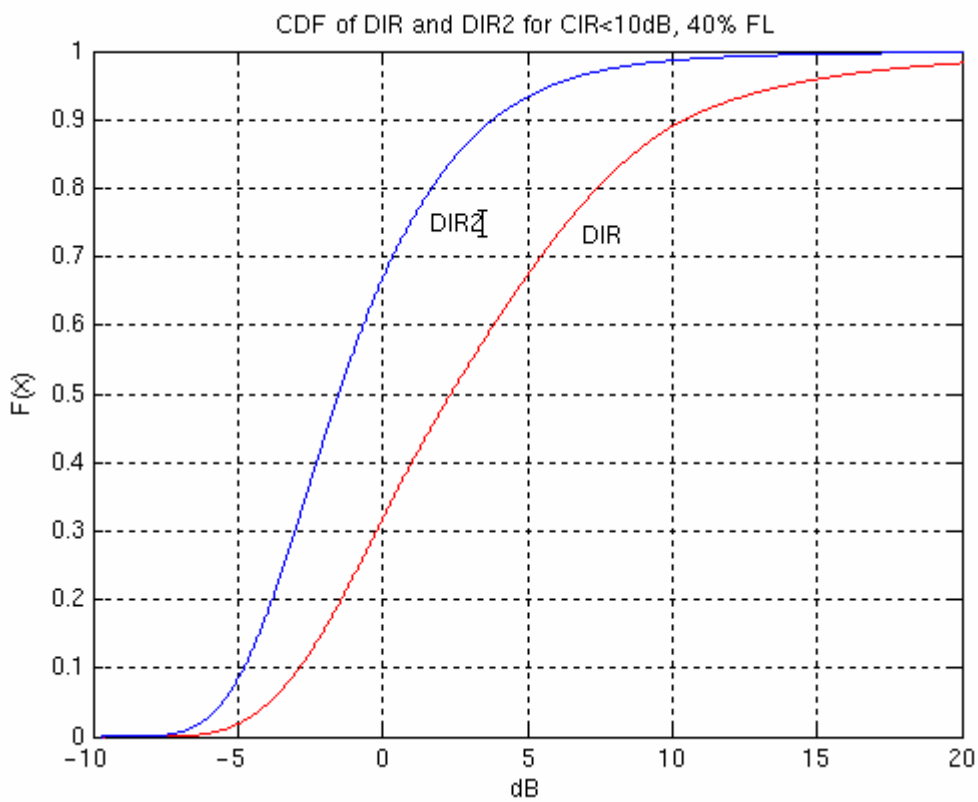

Figure 5: *DIR* and DIR_2 cdfs for *CIR*<10 dB and 40% FL

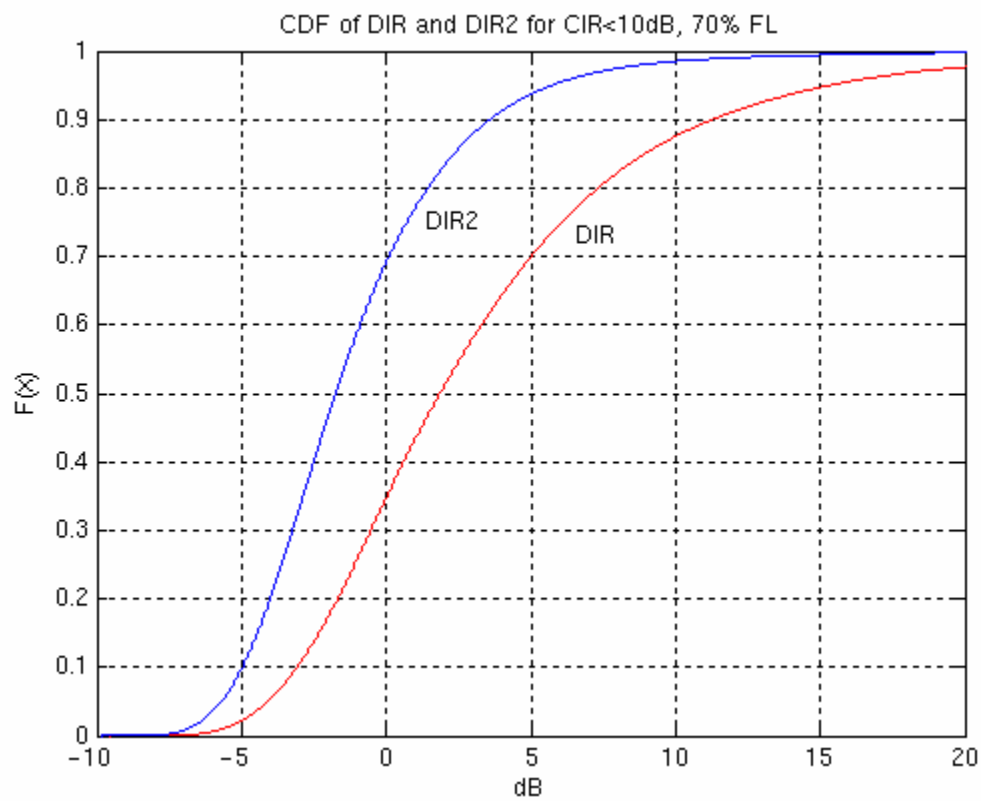

Figure 6: *DIR* and DIR_2 cdfs for *CIR*<10 dB and 70% FL

In the third set of results we look at the relative strengths of the strongest co-channel and adjacent channel interferers to determine how many co-channel and adjacent channel interferers are necessary to accurately characterize the interference environment for the SAIC link level simulations. This is done by comparing the overall CIR statistics with the individual CIR statistics for the strongest co-channel and adjacent channel interferers to determine the percentage contribution of each interferer towards the total interference.

For a 40% frequency load Figure 7 compares the cdf of the overall burst level *CIR* (or C/I_{tot}) with the cdfs of individual burst level CIR_{cck} (or C/I_{cck}) for the five strongest co-channel interferers. In the figure, the five strongest co-channel interferers are arranged in decreasing order of strength, with I_{cc1} denoting the strongest co-channel interferer and I_{cc5} denoting the fifth strongest co-channel interferer.

Figure 8 shows the corresponding set of *CIR* and CIR_{ack} (or C/I_{ack}) cdfs for the five strongest adjacent channel interferers. Here too, the adjacent channel interferers are arranged in decreasing order of strength, with I_{ac1} denoting the strongest co-channel interferer and I_{ac5} denoting the fifth strongest co-channel interferer. The C/I_{tot} curve in Figure 8 is the same as that shown in Figure 7. Note that I_{tot} is the total sum of the powers of all the co-channel as well as adjacent channel interferers.

Figures 9 and 10 show the corresponding set of cdfs for the 70% frequency load case. Note all *CIR* values were used to generate the curves shown in Figures 7, 8, 9, and 10.

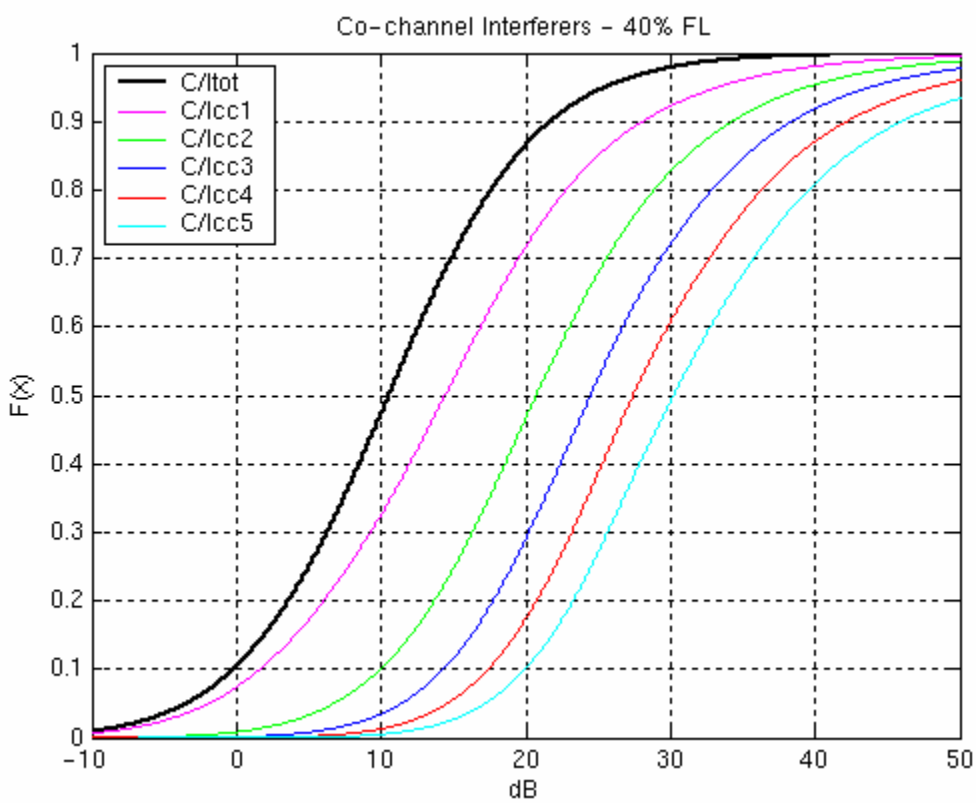

Figure 7: Relative strengths of five strongest co-channel interferers for 40% FL

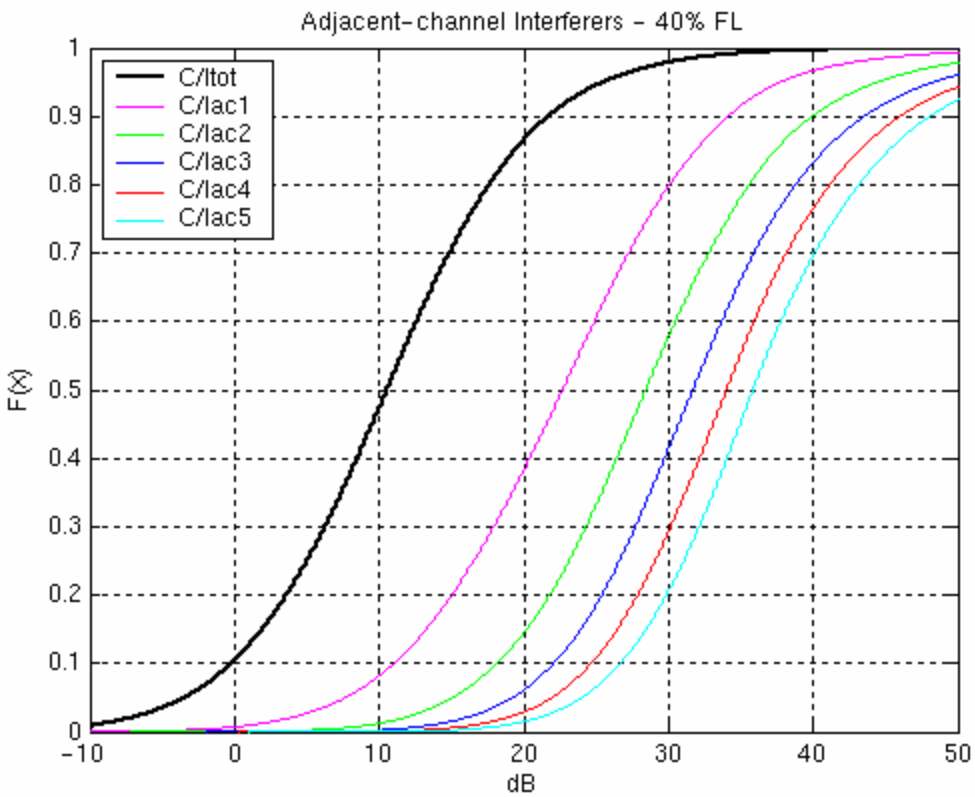

Figure 8: Relative strengths of five strongest adjacent-channel interferers for 40% FL

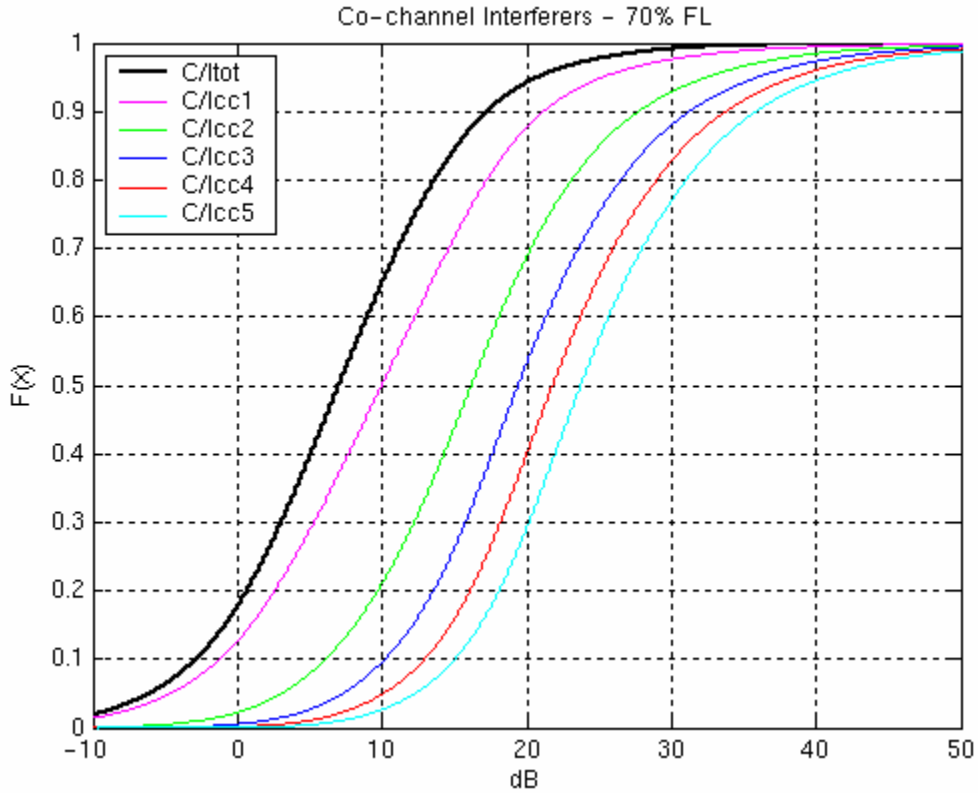

Figure 9: Relative strengths of five strongest co-channel interferers for 70% FL

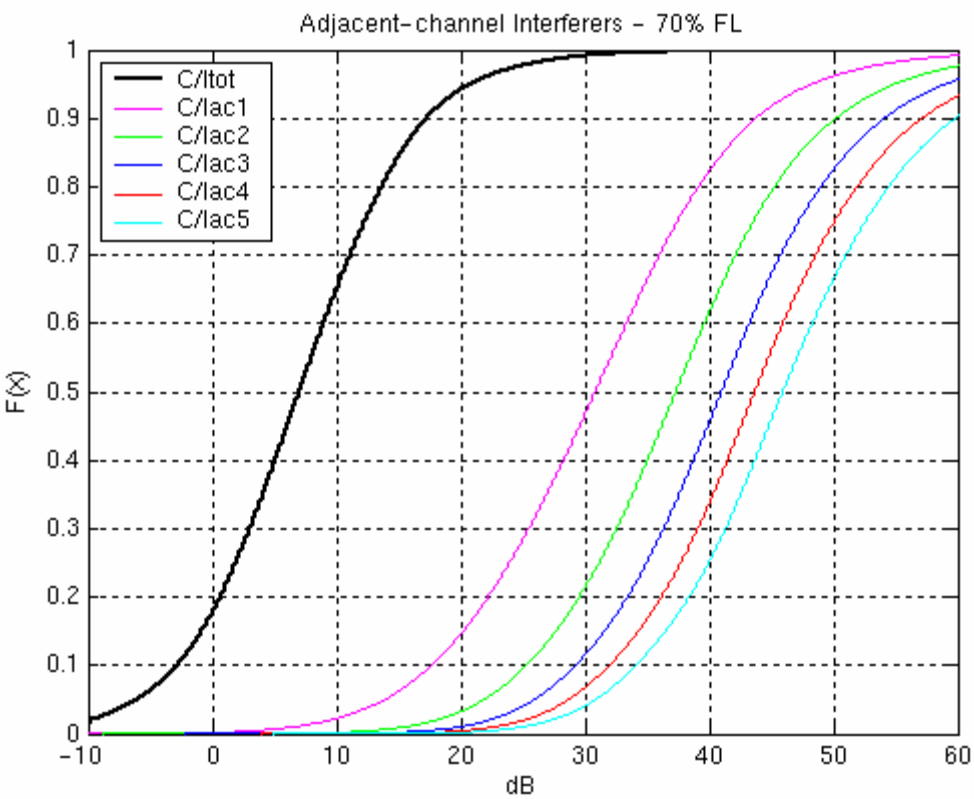

Figure 10: Relative strengths of five strongest adjacent-channel interferers for 70% FL

From the information presented in Figures 7, 8, 9, and 10 we can extract the 10th percentile and median data points and derive how much each individual interferer contributes towards to the total interference I_{tot}. The percentage contribution of the *k*th co-channel interferer is calculated as $100*I_{cck}/I_{tot}$ and the percentage contribution of the *k*th adjacent channel interferer is calculated as $100*I_{ack}/I_{tot}$. Figures 11, 12, 13, and 14 show the percentage contributions from the five strongest co-channel and adjacent channel interferers for 40% and 70% frequency loads.

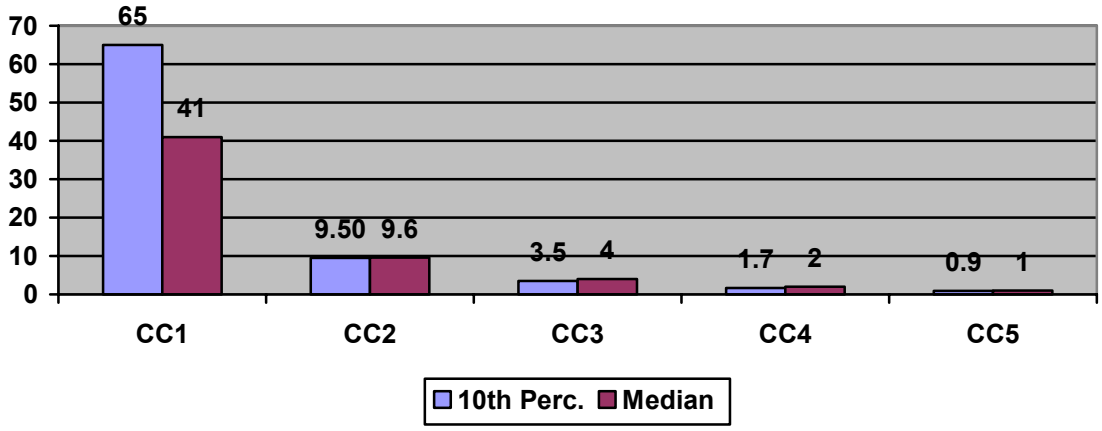

Figure 11: Percentage contribution ($100*I_{cck}/I_{tot}$) of the five strongest co-channel interferers for 40% FL

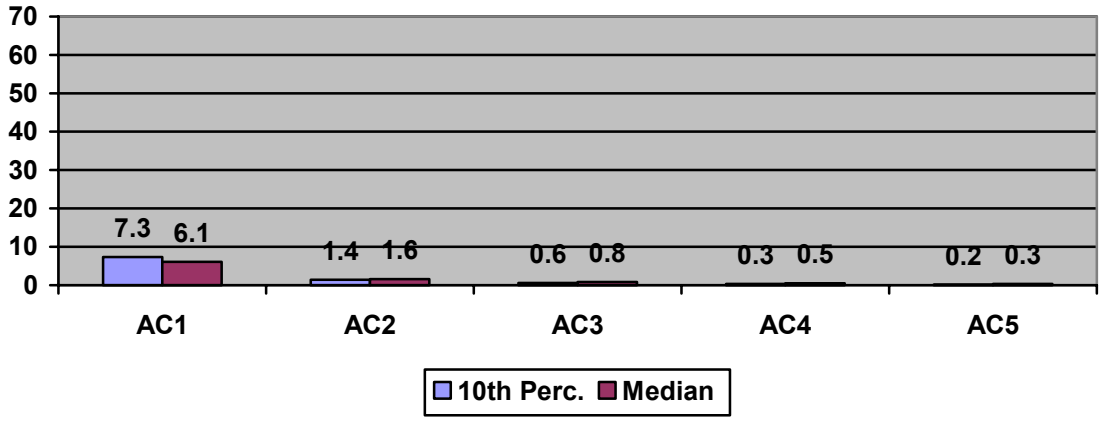

Figure 12: Percentage contribution ($100*I_{ack}/I_{tot}$) of the five strongest adjacent-channel interferers for 40% FL

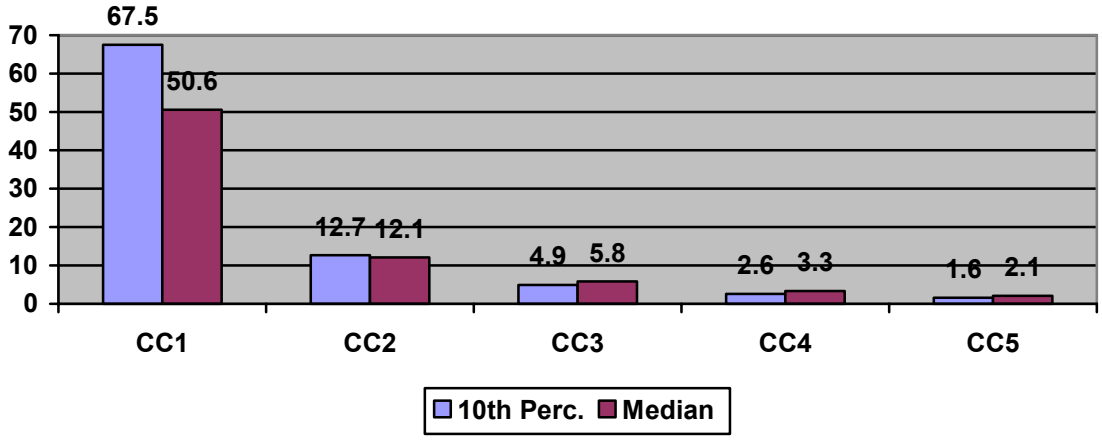

Figure 11: Percentage contribution ($100*I_{cck}/I_{tot}$) of the five strongest co-channel interferers for 70% FL

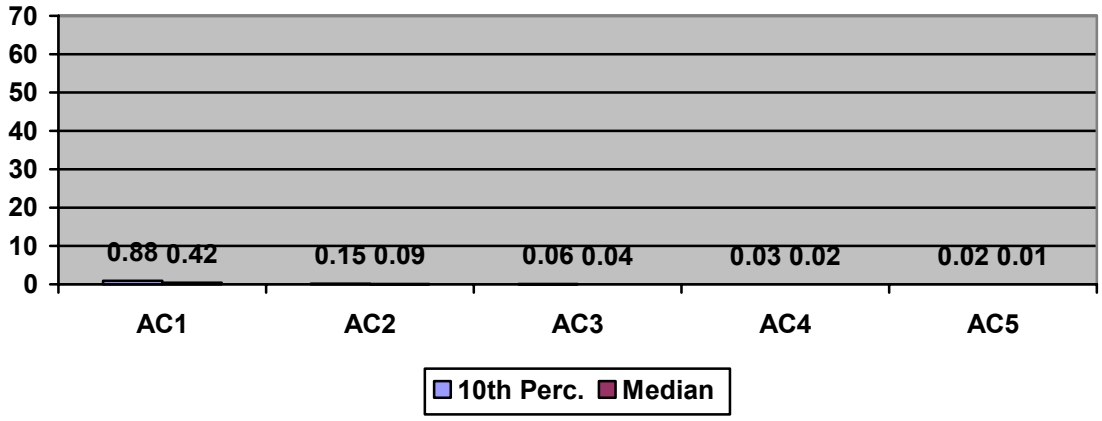

Figure 14: Percentage contribution ($100*I_{ack}/I_{tot}$) of the five strongest adjacent-channel interferers for 70% FL

5. Recommendation

Based on Figures 11, 12, 13, and 14, it is clear that for the 40% and 70% frequency load cases, the interference environment is dominated by co-channel interference. Our goal is to develop a recommendation for the number and type of interferers to model for SAIC link level simulations. Let us set a criterion that any interferer that contributes approximately 10% or more towards the total interference (I_{tot}) should be modeled as a separate interferer for the SAIC link level simulations. Applying this criterion to the numbers given in Figures 11, 12, 13, and 14 shows that for 40% and 70% frequency loads, the interference environment should be characterized by modeling two co-channel interferers at the link level. The interference power corresponding to all the other interferers that individually contribute less than 10% of the total interference power can be modeled as an additive white Gaussian noise interferer. This results in the following recommendation.

It is recommended based on the results presented in this contribution that for 40% and 70% frequency loads, the interference for SAIC link level simulations be characterized as two co-channel interferers and one additive white Gaussian noise interferer. It is recommended that the total interference power be distributed between these three components using the median values of Figures 7, 8, 9, and 10. This results in *DIR* and DIR_2 values of -1.6 dB and -6.9 dB for 40% load, while the corresponding values for 70% load are 0.2 dB and -4.9 dB, respectively. It is interesting to note that *DIR* and DIR_2 actually increase as a function of load for the configuration simulated. We suspect this is due to the fact that adjacent channel interference tends to become negligible with increasing load.

Note that SAIC link level simulations will need to be conducted across a range of *CIR, DIR, and* DIR_2 values. The median values specified above are convenient starting points for the link level characterization, but values greater and lesser than these will probably be required to adequately characterize performance over the entire expected range of values.

6. References

[1] GAHS-030015, “SAIC System Simulation Parameters for Characerization of Link Level Scenarios”.
[2] UMTS 30.03 v.3.2.0, “Selection procedures for the choice of radio transmission technologies of the UMTS”.
[3] GP-030187, “Interference statistics for evaluation of SAIC,” Ericsson.
[4] GP-030159, “Dependence of DIR and DIR2 statistics on frequency load,” Cingular.