Source:	**Motorola**
Title:	**SCM Fading, Urban Canyon Verification**
Document for:	**Discussion**

1. SUMMARY

This contribution investigates further details of the fading behavior of the spatial channel model, which is characterized by its narrow angle spread. These effects are examined and compared using the autocorrelation function, and the length of the simulated segment is considered.

2. AVERAGE FADING BEHAVIOR

When correlating over numerous time profiles of the complex fading envelope, the result is a classical Bessel function when all AoAs are sampled. When limited to a restricted range of AoAs, the correlation plot may be very much higher, and be real or complex as shown in [1]. The magnitude of the autocorrelation increases as the angle spread decreases, and it is a function of the AoA.

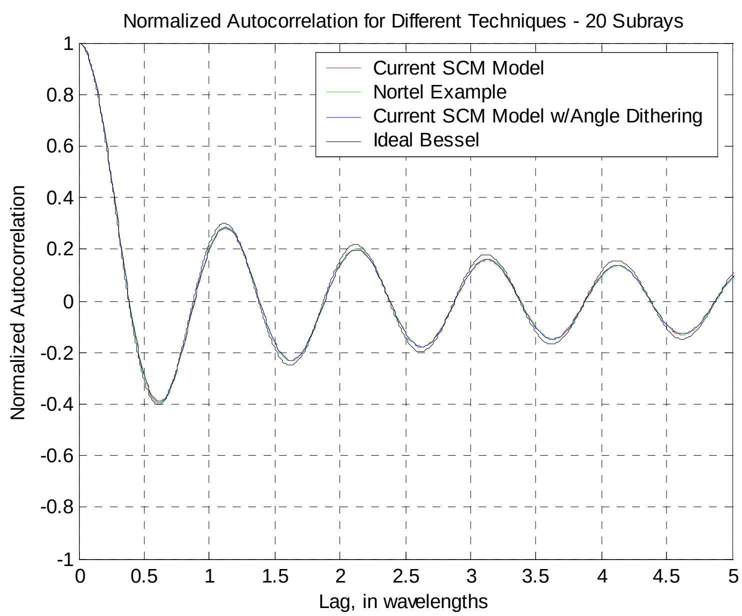

Figure 1, Fading Autocorrelation, σ_{AS}=35º, AoA=Random, with different sub-ray configurations

In order to evaluate the SCM fading behavior and compare to different models, the following three cases were defined in [1] and comparisons were illustrated. These same models will be used for further comparisons. They are:

a.) The SCM model with 20 sub-ray of equal power and Laplacian in angle with σ_{AS} = 35°
b.) The Nortel example[2] is shown where an equal angle spacing is used with a Laplacian power per sub-ray. The angles are randomly perturbed by a uniform distribution within a bin around each sub-ray, and the powers are correspondingly set with a Laplacian envelope according to the angles that were used.
c.) This example uses the SCM model with 20 equal power sub-rays, but includes a uniform randomizing of each of the angles within a bin around each sub-ray. The powers remain constant.

d.) Ideal correlation from an integral[3].

When averaging across uniformly random AoAs, the average behavior converges to the classical Bessel function for each of the fading models. Figure 1 illustrates the case where models a, b, & c, are evaluated with random AoA for each sampling interval. The results are all real-valued and indicate that the current SCM model, or models with additional randomization in angle or power are all comparable and produce a sufficiently good match to the ideal Bessel function when evaluated across the various possible angles of arrival.

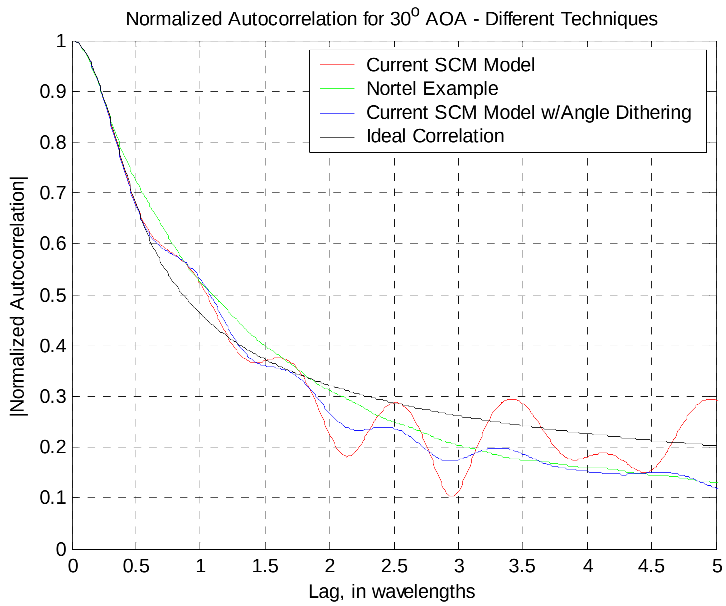

Figure 2, Autocorrelation (Magnitude), σ_{AS}=35º, AoA=30º with different sub-ray configurations

For specific AoAs, the correlation varies, and many examples were shown in [1]. Figure 2 compares the correlation for the different techniques when the AoA = 30º. The magnitude of the complex correlation is shown in this result. From this figure, it is observed that the three techniques are similar with the undithered SCM model having more variation at large lag times, however it produces a better match to ideal[3] at the important subscriber spacing of $\lambda/2$. The deviations from ideal are mainly due to the quantizing effect of having only 20 components. It should be noted that the variations in correlation will be different for every AoA that is evaluated, but when averaging over the AoAs, the result converges to the ideal Bessel function as shown in Figure 1.

3. CORRELATION FOR SHORT SEGMENTS

When fading profiles of limited duration are sampled, the fading correlation does not as closely resemble the average, but is more noisy. This is true for all types of fading models including the SCM.

In order to evaluate the variations expected for short fading segments, the following experiments were made using the three fading approaches given above by models a, b, & c. In each case, numerous 100λ fading segments were evaluated for their complex autocorrelation. To compare the results, the correlation magnitude was used as a statistical measure. The following figures plot the mean, 10% and 90% values of the correlation magnitudes. Note that the mean value (solid line) of the correlation magnitudes is different than the magnitude of the mean value of the complex correlation (dashed line), which was used previously in [1], and in Figures 1 & 2. This new measure is introduced since it is difficult to compare %-tiles of complex numbers without taking their magnitudes first.

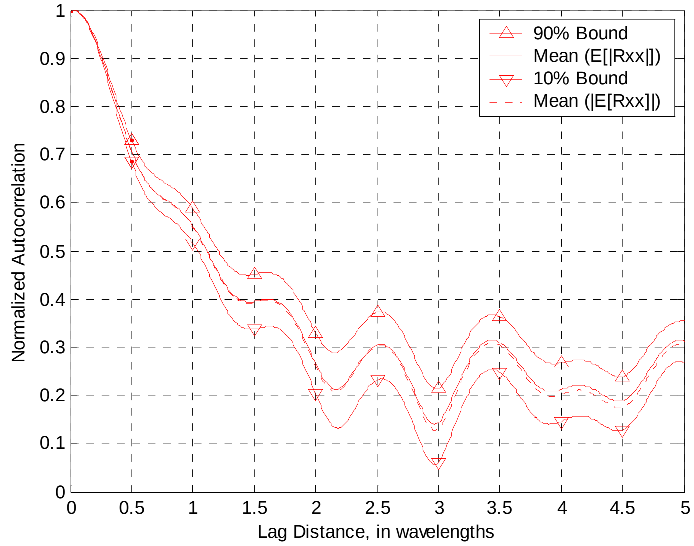

Figure 3, Standard SCM, AoA = 30 deg, 100λ fading segments

In Figure 3, the SCM model, which is characterized by 20 sub-rays of equal power and spaced with a Laplacian angle spacing is shown. The mean values using both averaging techniques produced nearly the same results as shown.

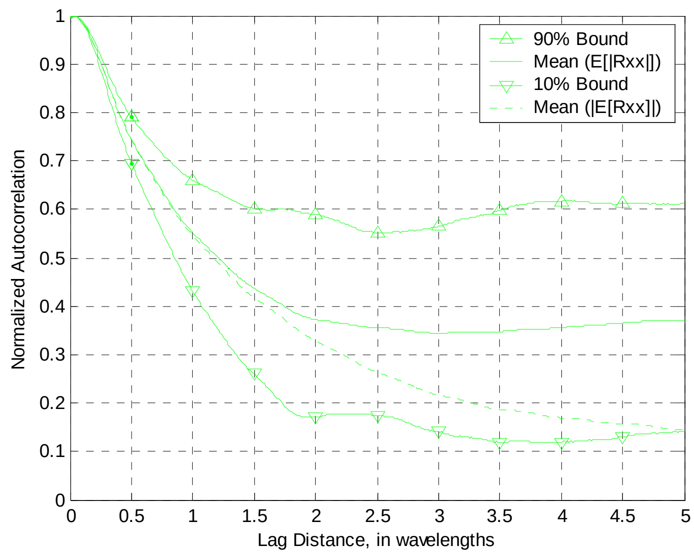

Figure 4, Nortel Example with 20 sub-rays, AoA = 30deg, 100λ fading segments

In Figure 4, the Nortel example[2] is shown to have a much larger deviation from the average, even at λ/2. Note also that the average of the magnitudes is much different than the average of the complex values. This is also evident in the 90%-tile being much higher than in the other models. It is believed that the difference in the averages is due to most of the power being concentrated in a few rays near the zero degree Laplacian center, which produces a higher spread of correlations for the individual channel realizations. When averaging in the complex domain, these larger magnitudes are cancelled by similar large magnitudes with opposing phases, whereas averaging in the magnitude domain retains a larger value.

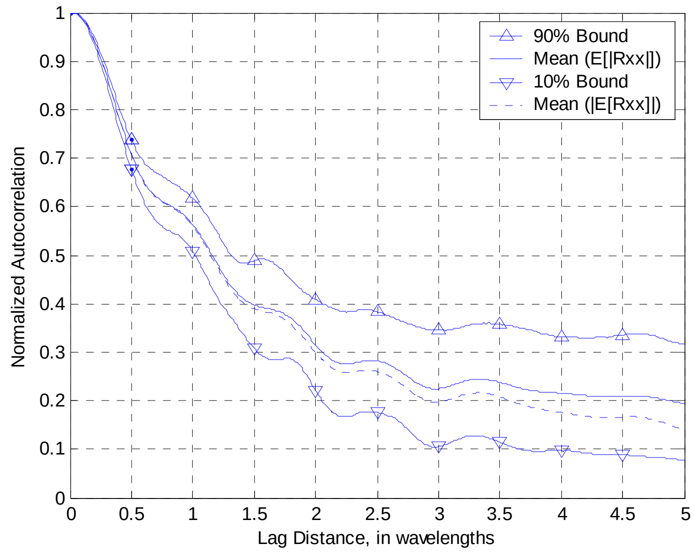

Figure 5, SCM model with Angle Dithering, AoA = 30 deg, 100λ fading segments

Figure 5 illustrates the third model being compared which extends the basic SCM with dithered AoAs for each of the 20 sub-rays. This model is somewhat more smooth at larger lag wavelengths compared to the SCM model, but the 10% & 90% deviations are slightly larger. The performance of this model appears to be similar to the SCM model at λ/2.

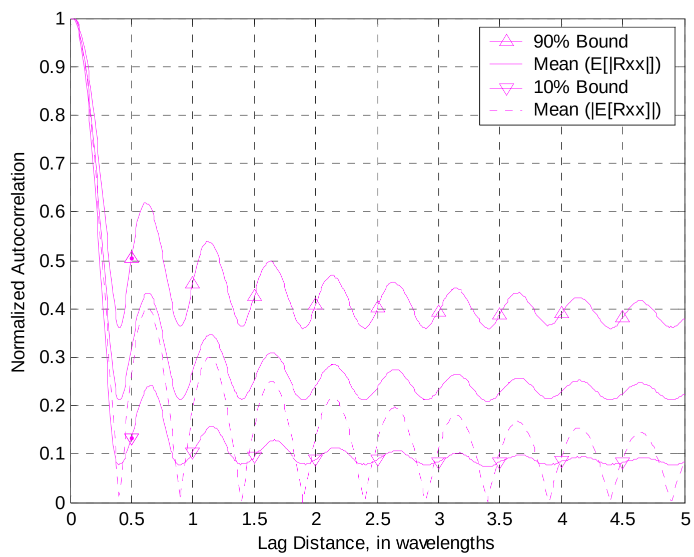

Figure 6, 20 sine wave with random phase and AoA distributed 0-2π, 100λ fading segments

Since the classical fading behavior is of interest for comparison purposes, a 20 sub-ray model was generated and the same statistical analysis is shown in Figure 6. In this experiment, a sine wave based fading model consisting of 20 sub-rays with phases and AoAs distributed randomly from 0-2π was modeled. Numerous 100λ fading segments were evaluated for their complex autocorrelation. In this plot, the average of the complex correlations produce the dashed line which is converging to the expected Bessel function. The other statistical measures, i.e. mean, 10%-tile and 90%-tile, illustrate the variation that is seen in correlating random 100λ segments. The statistical deviation seen in this experiment is similar to model c, which had dithered angles.

4. CONCLUSIONS

Additional details regarding the length of the fading segment have been characterized for the SCM by comparing statistical measures of correlation.

When comparing 100λ segments, the SCM model produced the least amount of variation from the mean, and appeared to be the most accurate at λ/2 spacings.

Statistical variations of correlation from the numerous 100λ segments appear to be somewhat larger when the sub-ray arrivals are random and uniformly distributed, i.e. classical Rayleigh fading assumption, than that produced by the SCM model. The result is similar to the dithered angle case shown in model c.

Much larger variations are seen in the correlation from the numerous 100λ segments when the sub-ray power envelope is a Laplacian. This may be due to fewer sub-rays having larger powers, and therefore producing higher correlations.

5. REFERENCES

[1] Motorola, SCM-086, "SCM Fading & Path Loss", Teleconference, December 19th, 2002.

[2] Nortel Networks, "SCM Model Correlations," SCM-065_v2, Teleconference, October 10th, 2002.

[3] J. Salz and J. H. Winters, "Effect of Fading Correlation on Adaptive Arrays in Digital Mobile Radio,''IEEE Tr. on Veh. Tech., Vol. 43, No. 4, pp. 1049-1057, November 1994.