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Capsim Application Note

Mobile Fading Channel Model

Mobile communication links can be simulated in Capsim using the *fade* star. This star is a baseband equivalent statistical model of the fading mobile channel. The theory is based on assuming that the field incident on the mobile's antenna is a superposition of plane waves with random phases arriving at different angles and exhibiting Doppler shift due to motion. The Doppler shift depends on the mobile speed, the carrier frequency, and the angle its propagation vector makes with the mobile velocity vector.

Figure 1 and 2 show the Capsim topology for testing the *fade* star. In the topology, the input is a DC level (real part= 1, imaginary part = 0). Since the *fade* star is a baseband equivalent model, a DC input corresponds to operation at the carrier frequency with no modulation. The *operate* stars implement the squaring and square root operations on the data so that the envelope of the fading signal can be computed. The other stars calculate the autocorrelation, cross correla-

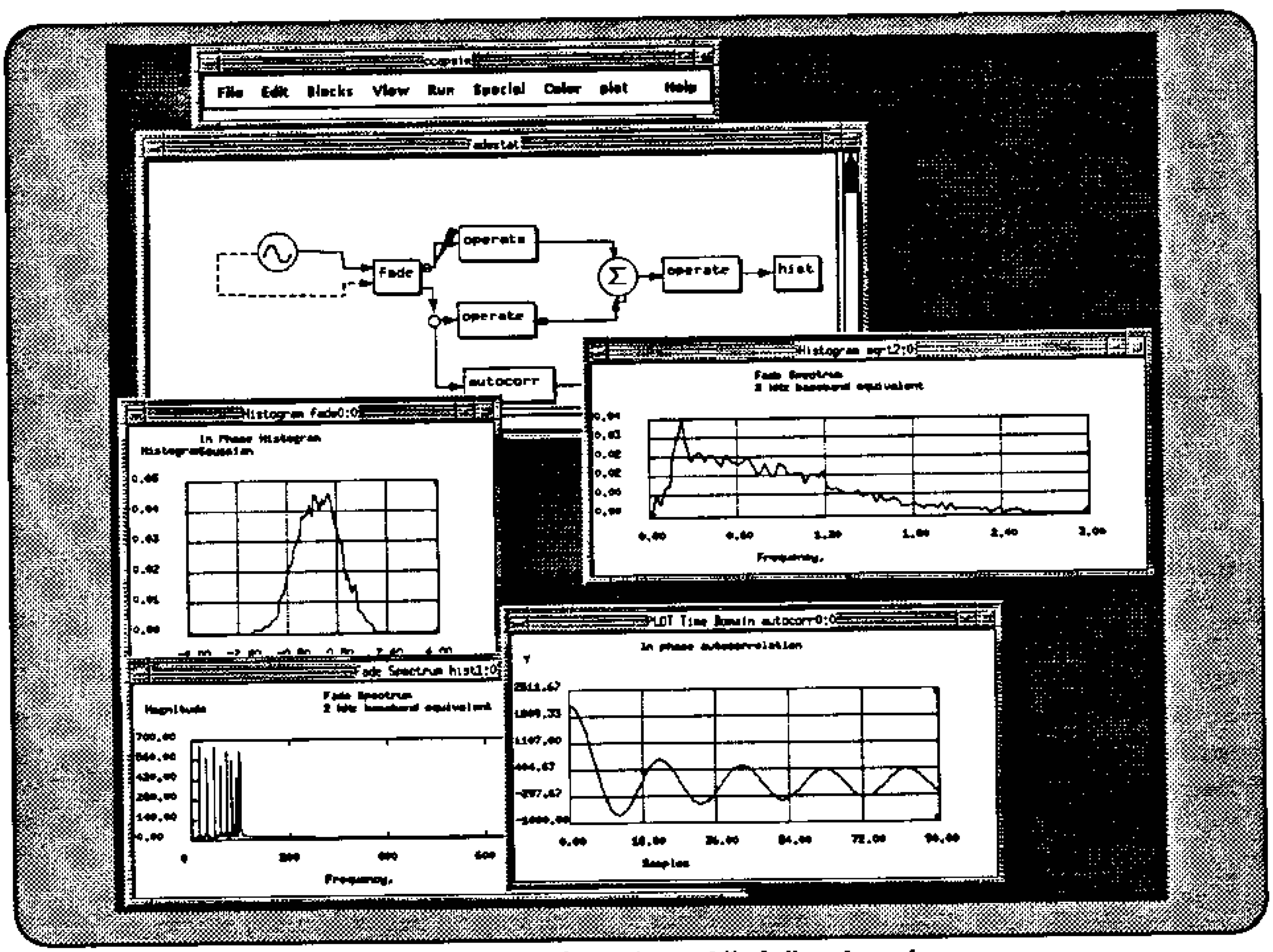

Figure 1 Topology for testing mobile fading channel

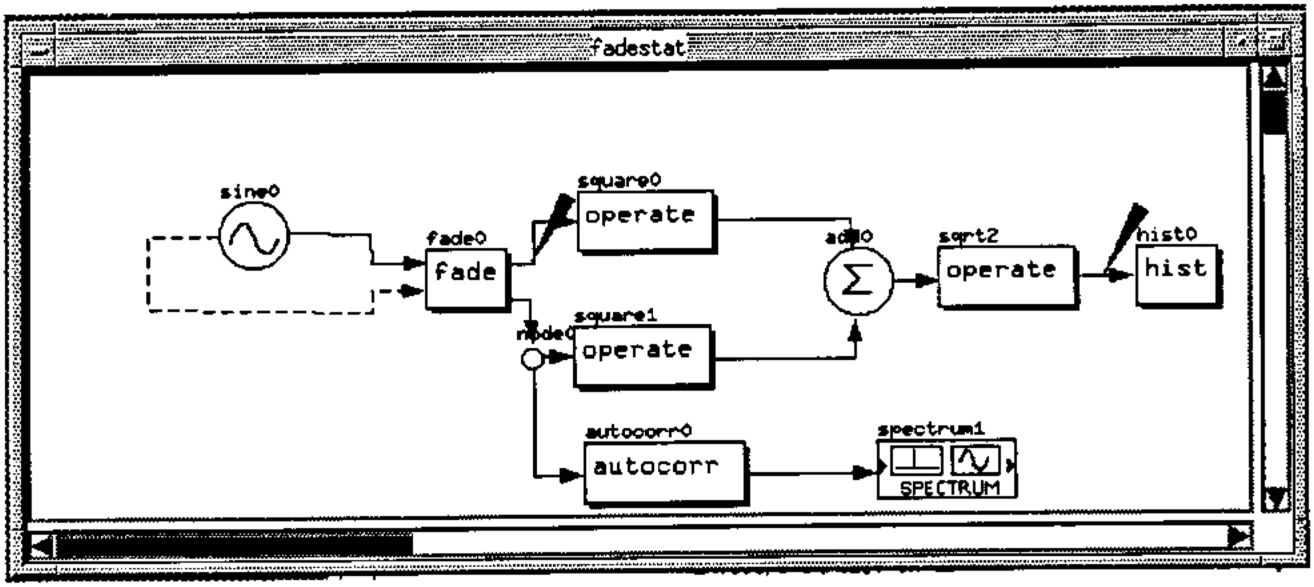

Figure 2. Mobile Fading Channel Test setup

tion, histograms, and spectrums of the various signals as indicated.

For a discussion on the model used, refer to "Microwave Mobile Communications", edited by William C. Jakes, John Wiley & Sons, New York, 1974, pp. 11-78. The simulated envelope is plotted in Figure 3. The vehicle velocity was 30 m/s. The carrier frequency was 1000 MHz. The envelope clearly shows the fading phenomena. It is in close agreement with measured signal variations. The *fade* star also includes a model for multipath fading. More than ten different multipaths can be used with individual power and delay specifications. The delay is modeled in the frequency domain so

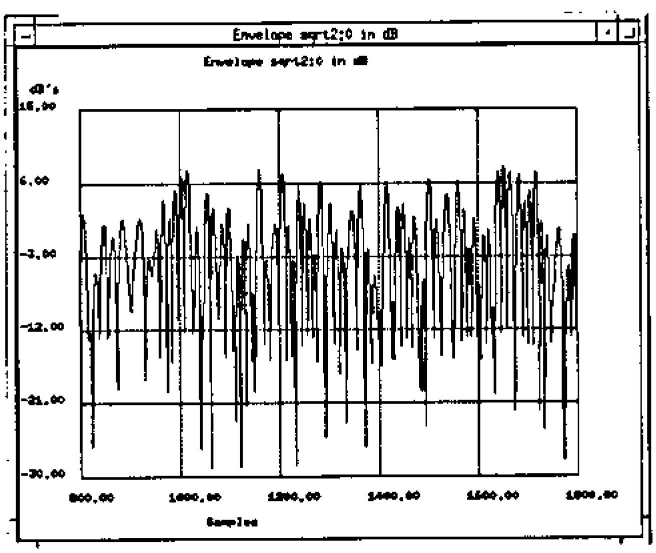

Figure 3. Fading Channel Envelope

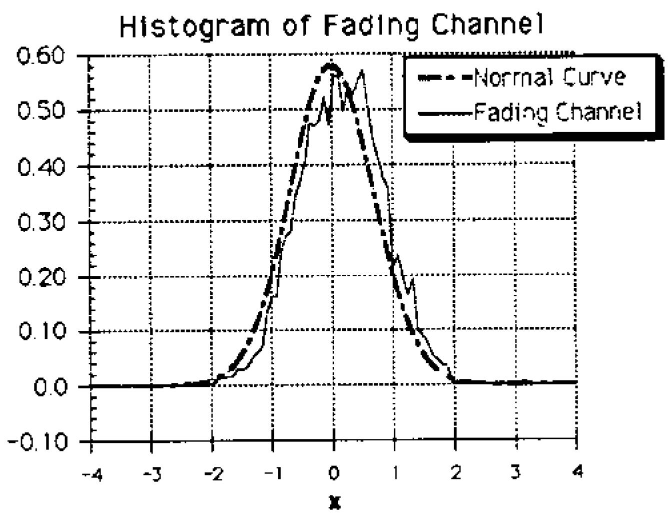

Figure 4. In-phase channel histogram

that the delay does not have to be a multiple of the sampling rate.
The technique is outlined in "A Software Multipath Fading Channel Simulator," by Nader Farahati, Technophone Limited, July 1989.

In the model a large number of plane waves are added with random phase and angle of arrival to produce the fading channel impulse response. The histogram of the in-phase channel of the fade star is shown in Figure 4. The histogram closely follows the Normal curve corresponding to a gaussian

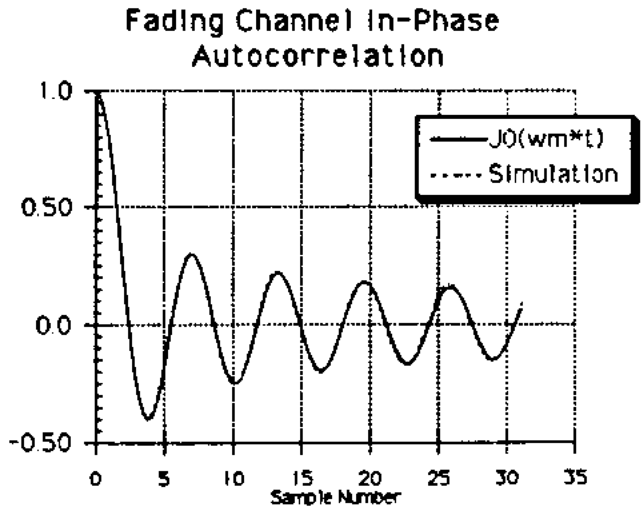

Figure 5. Simulated and calculated autocorrelation function

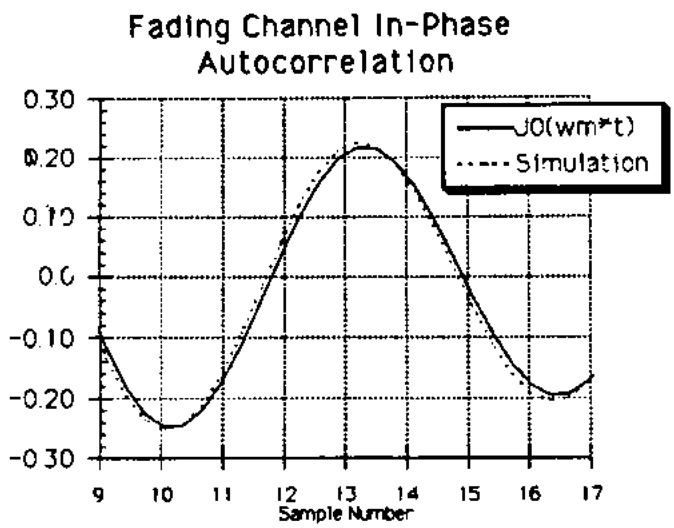

Figure 6. Closeup View

probability density function. It can be shown that the autocorrelation function of the in-phase and quadrature phase samples of a fading mobile channel, based on the model presented by Jakes, is $J_0(2\pi f_m \tau)$ where f_m is the Doppler shift frequency. The autocorrelation obtained by simulation and the theoretical results above are compared in Figure 5. In Figure 6, a close up of the curves is shown which illustrates the accuracy of the simulation.

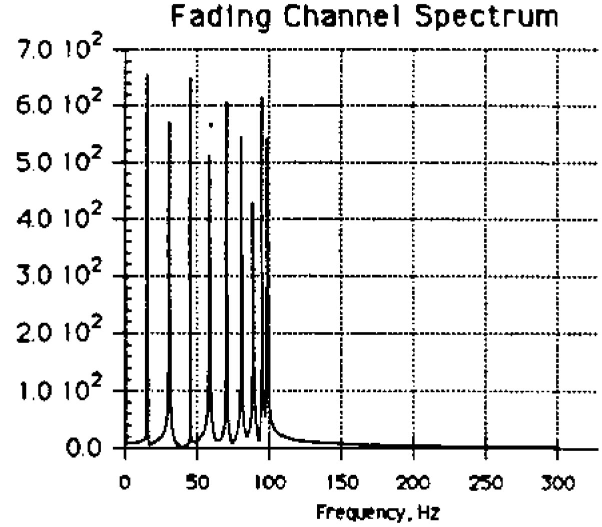

Figure 7. Spectrum of in-phase channel

The spectrum of the in-phase channel is show Figure 7. This spectrum clearly shows the broa ing of the spectrum due to Doppler shift cause vehicle motion. In fact, the maximum shift ca seen to correspond to $f_m = v/\lambda$ where λ is wavelength of the carrier (1 GHz).

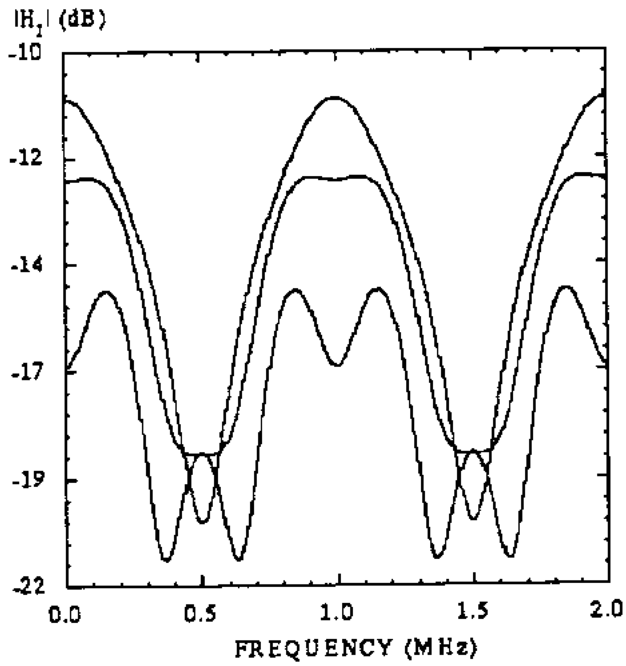

Figure 7. Overlaped spectrums of the in-phase component of the time varying channel

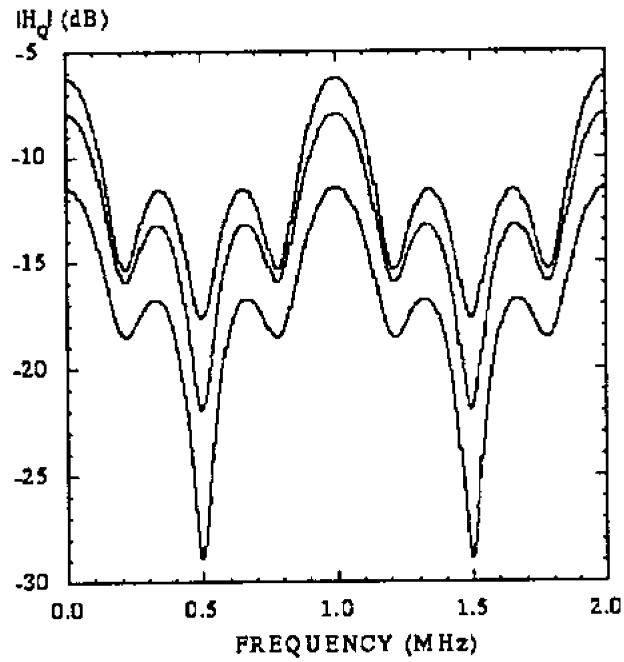

Figure 8. Overlaped spectrums of the quadrature-phase component of the time varying channel

Time Varying Characteristics

Figs. 7 and 8 illustrate the time-varying spectrums of the in-phase and quadrature-phase components of the complex baseband multipath Rayleigh fading mobile communication channel, respectively. The channel is composed of 4 multipaths and each path is the summation of 15 scattered signals. The mobile velocity is 45 mi/hr. The overlapped spectrum is recorded with equivalent time intervals of 500 transmitted symbols. The changing channel characteristics due to doppler shift are clearly illustrated.

Conclusion

This application note has described a multi-path Rayleigh fading mobile communication channel that can be used as the bases for testing the performance of various modulation techniques. In future work, we will describe the performance of a number of digital modulation techniques and adaptive equalization algorithms in a mobile fading channel communication link. We will also investigate the performance of blind adaptive equalizers in tracking the channel.

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