A Computer Generated Multipath Fading Simulation for Mobile Radio

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Abstract—**A brief description is presented of a computer simulation of the Rayleigh distributed fast fading encountered in mobile radio. This simulation should be of interest to all those whose studies involve parameters of a mobile system that interact strongly with the radio environment.**

IN THIS short paper, a computer simulation of the Rayleigh envelope time function is described. The fluctuations of signal envelope in a mobile-radio environment are due to the severe multipath encountered. The model used here for this multipath environment is the scattering model of R. H. Clarke [1]. Clarke assumes that energy arrives at the receiver by way of a number of indirect paths. The phase and angle of arrival of each component wave is completely random and statistically independent. There is no direct wave, nor coherent reflected wave, as may sometimes occur in practice when a line-of-sight path exists from transmitter to the receiver [2]. With Clarke's model, the "incoherent field" model, the amplitude statistics of the received signal envelope are Rayleigh, and the phase is uniformly distributed. Moreover, the input spectrum is limited to a maximum f_D, the Doppler frequency given by the ratio of vehicle speed to carrier wavelengths, i.e.,

$$f_D = v/\lambda. \tag{1}$$

A hard-wired simulator [3] based on this model has been constructed and is in use in our laboratory. A computer simulation based on the same model has also been very useful, particularly for studies of codes and coding schemes for the radio channel [4]–[6]. With the computer simulation, proposed signaling algorithms can be quickly screened for their suitability. No delays are needed to construct hardware.

In the hard-wired laboratory simulator, two independent Gaussian noise sources are added in time quadrature. The simulation of the fading spectrum appropriate to a mobile radio is obtained by shaping the spectrum of the noise sources. In the computer simulation, the Gaussian distributed Fourier coefficients of the noise are obtained from a random number generator. Each coefficient is weighted by a shaping factor. This spectral weighting factor depends on the antenna orientation and gain [1], [7]. The spectrum chosen for our simulations is appropriate to a vertical monopole antenna.

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      SUBROUTINE RAYFDE(FD,X)
C     RETURNS 200 RAYLEIGH FADED ELEMENTS (IN DB1) AT 5 MSEC INTERVALS
      DIMENSION X(200),Z(200),F(100)
      PI=3.14159265
      DO 17 I=1,200;X(I)=0.;17 Z(I)=0.
      IR=ITIMEZ(0)
      N=200;IM=FD
      DO 20 I=2,IM
      T=I -1;P=SQRT(1.-(T/FD)**2)
      20 F(I)=1./SQRT(P)
      IMM=IM+1;P=FLOAT(2.*IM-1);P=FLOAT(IM-1)/SQRT(P)
      P=FLOAT(IM)*(PI/2.-ATAN(P));F(IMM)=SQRT(P)
C     ARRAY F CONTAINS THE FILTER FACTORS
      DO 30 I=2,IMM
      30 X(I)=F(I)*RNORMS(IR)
      DO 40 I=2,IMM
      40 Y(I)=-F(I)*RNORMS(IR)
C     RNORMS IS A RANDOM NUMBER GENERATOR WITH GAUSSIAN DISTRIBUTION
      CALL FFTRAN(N,X,Y)
      CALL FACTR(N)
C     FFTRAN AND FACTR ARE FAST FOURIER TRANSFORM ROUTINES
      DO 50 I=1,200
      50 Y(I)=0
      DO 60 I=2,IMM
      60 Y(I)=F(I)*RNORMS(IR)
      DO 70 I=2,IMM
      70 Z(I)=-F(I)*RNORMS(IR)
      CALL FFTRAN(N,Y,Z)
      CALL FACTR(N)
      S=0.
C     TWO INDEPENDENT AND FILTERED NOISE SOURCES ARE COMBINED IN
      QUADRATURE
      DO 80 I=1,200
      X(I)=X(I)**2+Y(I)**2
      80 S=S+X(I)
      S=S/200
      Q=10./ALOG(10.)
      DO 90 I=1,200
      90 X(I)=Q*ALOG(X(I)/S)
C     OUTPUT IS THE ARRAY X CONTAINING 200 LEVEL POINTS (IN dB
      NORMALIZED TO A 0 dB MEAN).
      RETURN
      END
```

Fig. 1. Listing of routine.

A listing of the computer routine is given in Fig. 1. Briefly, the routine creates a sequence of amplitude elements equally spaced in time producing a multipath fading signal envelope waveform having Rayleigh statistics. The Doppler frequency (1) is an input parameter, and the output time sequence is stored in an array X generated by a call to

RAYFDE(FD,X).

The amplitude values stored in X are normalized to have a zero decibel mean, i.e., $\bar{X}^2 = 1$. As written, 200 elements are returned spaced 5 ms apart, and an envelope is produced that is 1 s long. A change in the array size from 200 to 1000 will result in a 1 s sequence with elements spaced 1 ms apart. Longer sequences can be generated by rescaling the Doppler frequency to correspond to an appropriate harmonic number. For example, for a 10 s sample with 5 ms spacing, the input parameter FD should be a times ten multiple of the true Doppler frequency.

A random time sequence generated by RAYFDE is shown in Fig. 2. This particular sample was taken at 12 mi/h and at 850 MHz. Each call generates an independent sequence. Data obtained using these time

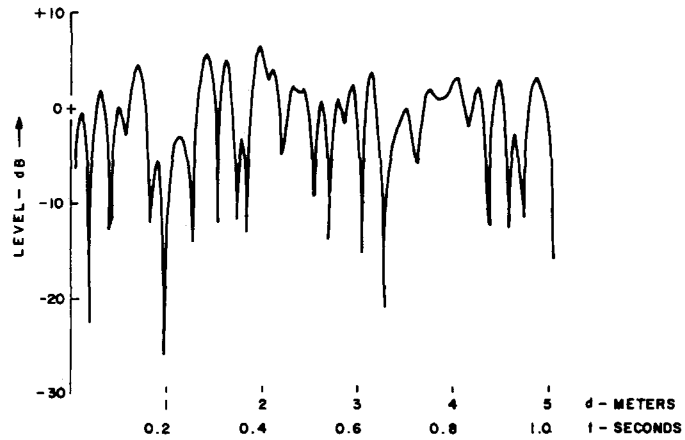

Fig. 2. Rayleigh envelope function.

sequences are consistent with those obtained from our laboratory simulator. The advantage in the computer simulation is its convenience—results on a proposed circuit can be obtained in minutes rather than weeks. The disadvantage of the computer simulation is its expense if rates of occurrence of rare events (probability $<10^{-3}$) are being studied.

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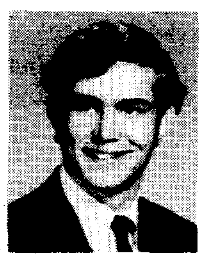
Contributors



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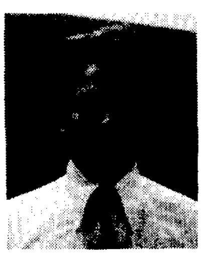

Karl Jakus was born in Hungary and in 1956 emigrated to the United States. He received the B.S. degree in mechanical engineering from the University of Wisconsin, Madison, and the M.S. and Ph.D. degrees in aeronautical engineering, from the University of California, Berkeley.

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