

floors, warehouses, campuses and hospitals.⁵ All the reported wideband measurements and modellings are concerned with the statistics of the multipath spread. The only attempt in modelling the arrival of the paths in a building, is reported by Saleh and Valenzuela.⁴

Saleh and Valenzuela⁴ use the mathematical model originally suggested by Turin for urban radio data communications.⁷ In this model, the complex envelope of the channel impulse response is represented by

$$h(t) = \sum_{k=1}^L \alpha_k \delta(t - \tau_k) e^{j\theta_k} \quad (1)$$

The transmitted impulse $\delta(t)$ is received as the sum of L paths. The path k has amplitude α_k , delay τ_k and carrier phase shift θ_k . Based on the measurements in a research laboratory, the arrival of the paths is modelled as a Poisson process. The paths are presumed to have independent uniform phases, and independent Rayleigh amplitudes.

This letter reports the discrepancies following the Poisson arrival presumption and, based on empirical data collected from different manufacturing floors and college campus areas, presents a more accurate modified Poisson process to fit the arrival of the paths.

Measurements: The measurement set-up for the multipath propagation experiments, involved modulation of a 910 MHz signal by a train of 3 ns (3 dB width) pulses with 500 ns repetition period.¹ The stationary receiver included a digital storage scope and a personal computer. The transmitter and the receiver used vertically polarised quarter-wave dipole antennas placed about 1.5 m above floor level. The transmitter was moved to various locations in the site, and the received multipath profiles were stored in the computer. The distance between the transmitter and the receiver varied between 1 and 50 m. A total of about 480 profiles were collected from measurements made in five areas on three different manufacturing floors¹ and two areas on college laboratory floors. Each profile was an average over time of 64 profiles collected over 15–20 s. A typical multipath profile, obtained from one of the locations is shown in Fig. 1.

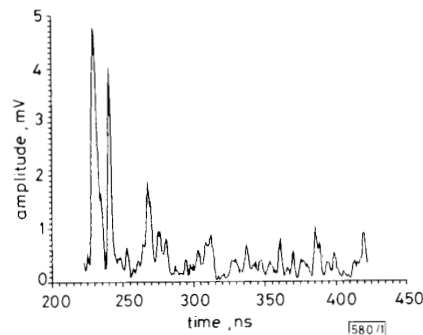


Fig. 1 Multipath profile obtained from location on manufacturing floor

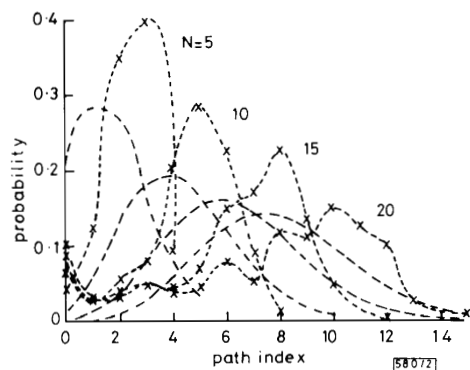


Fig. 2 Comparison of empirical and theoretical Poisson distribution for manufacturing floor areas

Results and discussion: For the path arrival distribution, the arrival time of the paths in each profile is divided into 5 ns bins. The empirical curves were obtained by counting the number of paths in the first N bins of each measured profile. The probability of occupancy in each bin was then plotted against the arriving delay (path index) and these points were connected by curves for clarity. The procedure is repeated for arriving paths in the first 5, 10, 15 and 20 bins. After careful visual inspection of many profiles, the threshold level employed to detect a genuine path in any bin was fixed at 30 dB below the highest peak in the profile.

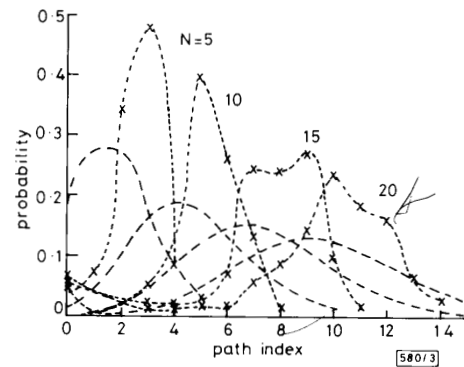


Fig. 3 Comparison of empirical and theoretical Poisson distribution for college laboratory areas

Figs. 2 and 3 show a comparison between the empirical path number distributions and the theoretical Poisson distributions, for various values of N , for the manufacturing floor areas and the college campus areas, respectively. The theoretical curves governed by the Poisson hypothesis use a mean path arrival rate λ for any value of N . The Poisson path number distribution is then given by

$$P_r(K) = \frac{\lambda^K}{K!} e^{-\lambda}$$

This is plotted as a continuous curve though it has values for only integer path numbers. We observe considerable discrepancies between the empirical and the Poisson distributions for all values of N . This discrepancy reflects a tendency of the paths to arrive in clusters, rather than in a random manner. To explain similar discrepancies a modified Poisson model was proposed by Suzuki for urban radio channel modelling.⁶

According to the modified Poisson model, whenever there is a path in a bin, the mean arrival rate for the next bin is changed by a factor of K . The process becomes a standard Poisson sequence for $K = 1$. Depending on whether K is greater or less than 1, the probability that there will be another path within the next bin increases or decreases, respectively. The underlying path occupancy rate λ_i , is calcu-

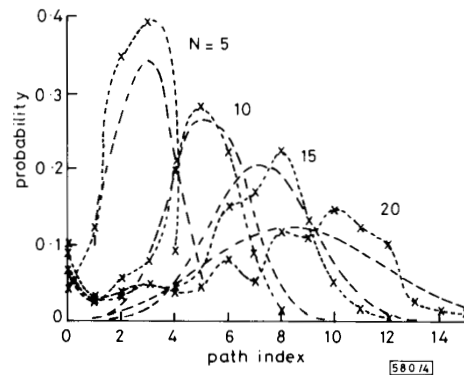


Fig. 4 Comparison of empirical and modified Poisson distribution for manufacturing floor areas

lated from the empirical path occupancy rate r_i by the following relation:

$$\lambda_n = \frac{r_n}{(K-1)r_{n-1} + 1} \quad n \neq 1$$

where $\lambda_1 = r_1$. The path number distribution is then calculated successively, using the recursive formulas given for this model in Reference 6. Figs. 4 and 5 show a comparison between the empirical path number distributions and the modified Poisson distributions for the manufacturing floors and college campuses, respectively. The curve fittings show considerable improvement over those of the Poisson model.

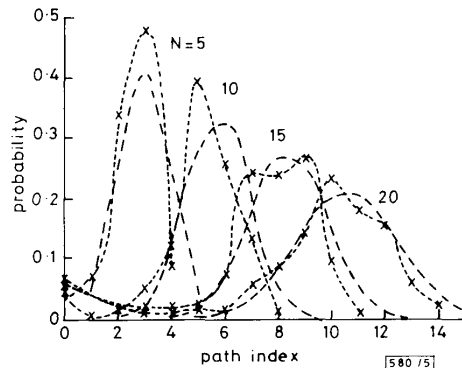


Fig. 5 Comparison of empirical and modified Poisson distribution for college laboratory areas

This improvement is because the modified Poisson model utilises the empirical probability of occupancy for each bin, whereas the Poisson model just uses the sum of the probabilities of occupancy for all bins. The optimum values of K calculated for the manufacturing floors and the campus environments are shown in Table 1.

Table 1 OPTIMUM VALUES OF K

Area	Number of locations	Number of bins N			
		5	10	15	20
Manufacturing floors	288	1.184	0.904	1.03	2.46
College laboratories	196	0.892	0.64	0.61	0.75

Conclusions: Fading multipath profiles obtained from several different manufacturing floors and some college laboratories at 910 MHz, have been used to model the arrival of the paths. The empirical distribution was compared with the Poisson and the modified Poisson distributions and the modified Poisson model is shown to provide a better fit. This observation indicates that the paths tend to arrive in clusters rather than in a random manner.

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10 MHz CMOS OTA-C VOLTAGE-CONTROLLED QUADRATURE OSCILLATOR

Indexing terms: Circuit theory and design, Oscillators, Integrated circuits, Nonlinear networks

A quadrature-type voltage-controlled oscillator with operational transconductance amplifiers and capacitors (OTA-C) is presented. A monolithic integrated CMOS test circuit is introduced to verify theoretical results. The attainable frequency range of oscillation of the chip test circuit is 3-10.34 MHz. The total harmonic distortion (THD) is 0.20-1.87% for corresponding peak-to-peak amplitude voltages between 100 mV and 1 V. This amplitude can be controlled either by using a diode connection of two MOS transistors or a proposed nonlinear resistor.

Introduction: The quadrature mode of operation is a well-known mode of waveform generation in the field of sinewave oscillators.¹⁻³ Two sinewaves in quadrature, that is with 90° phase difference, are generated. This is accomplished with a two-integrator loop. Besides this, some form of regeneration is usually included to ensure that the oscillation is created. The poles are initially located in the right half-plane (RHP) of the complex frequency plane and then pulled back by a nonlinear amplitude limiter.

To make a quadrature oscillator into a voltage-controlled oscillator (VCO), the integrators can be implemented using OTAs. The output current of a CMOS-OTA is controlled by the differential input voltage and its transconductance gain g_m . Furthermore, g_m can be varied over several octaves by adjusting an external DC amplifier bias current I_{abc} ,⁴ i.e.

$$g_m = h_c \sqrt{I_{abc}} \quad (1)$$

where h_c is a process-dependent parameter.

In this letter an integrated CMOS OTA-C quadrature VCO using a 3 μ m double metal technology (processed by MOSIS, Marina del Rey, CA) is presented. The frequency of oscillation can be externally adjusted by nearly two octaves with a THD less than 1.9%. The real part of the poles can be adjusted, in practice, independently of the frequency of oscillation.

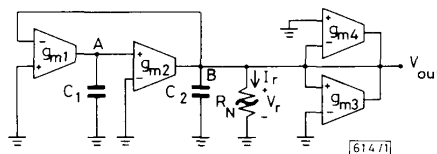


Fig. 1 Proposed OTA-C quadrature oscillator structure

Theory: The proposed quadrature VCO architecture⁵ is shown in Fig. 1. It has one inverting (g_{m1} , C_1) and one noninverting integrator (g_{m2} , C_2). R_N is a nonlinear resistor whose i/v characteristics are depicted in Fig. 2a. R_N provides the nonlinear amplitude limiter function. Implementations are discussed later. The OTAs associated with g_{m3} and g_{m4} allow