results are shown in Fig. 3 where a comparison with the computations give good general agreement. The values of $\varepsilon_r = 15$ and $\sigma = 0$ for concrete are taken from the literature [7, 8]. Our computations show that around these values, the path loss predictions from our model are not sensitive to changes in ε_r and σ. Our model has so far proven to be satisfactory for application to various city street scenes and an indoor scene with this relatively simple corridor geometry. It is now being tested in a more complex environment for a laboratory scene with furniture, equipment and building columns.

27 September 1994
Electronics Letters Online No: 19941393

S.Y. Tan and H.S. Tan (*School of Electrical and Electronic Engineering, Nanyang Technological University, Singapore 2263, Republic of Singapore*)

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Nonlinear phase precoding for personal communications

W. Zhuang and V. Huang

Indexing terms: Channel coding, Indoor radio

The authors present a novel channel precoding technique using nonlinear phase distortion to pre-equalise a slowly fading channel with severe intersymbol interference. It is shown that the precoder can significantly improve the transmission performance of a personal communications system.

Introduction: In a high bit rate indoor wireless communications system, the intersymbol interference (ISI) due to multipath can dramatically increase the transmission bit error rate (BER). The problem can be solved without increasing the complexity of the portable unit by moving the equalisation function from the receiver of the portable unit to the transmitter of the base station. The challenge of this channel precoding (pre-equalising) is to ensure the stability of the precoder even in equalising a non-minimum-phase channel. An adaptive channel precoder has been proposed for phase modulation over a slowly fading channel [1], which needs a linear transversal filter with a large number of taps in order to effectively equalise a fading channel with severe ISI. This Letter proposes a new approach to phase precoding, which nonlinearly predistorts the phase of the transmitted signal in order stabilise the precoder and to obtain an ISI-free received signal.

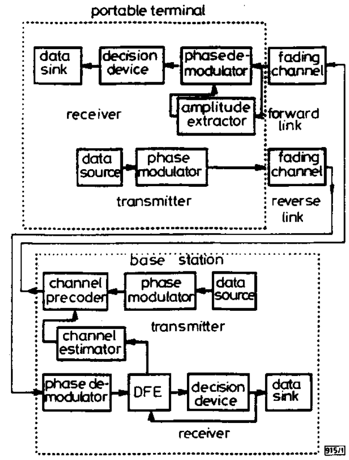

Fig. 1 *Functional block diagram of system model*

System description: Fig. 1 is a functional block diagram of the system where the precoder is used. The system operates in a time-division multiple access (TDMA) time-division duplex (TDD) scheme. In the reverse link, an adaptive decision-feedback equaliser (DFE) is used in the base station receiver to reduce the ISI. The channel estimator estimates the channel impulse response based on the tap coefficients of the DFE, which is then used in the precoder of the base station transmitter to predistort the signal transmitted in the forward link, so that the signal received at the portable terminal is ISI free. The precoding is based on the fact that an indoor radio channel fades so slowly that changes of the fading characteristics over the duration of one frame of data can be neglected.

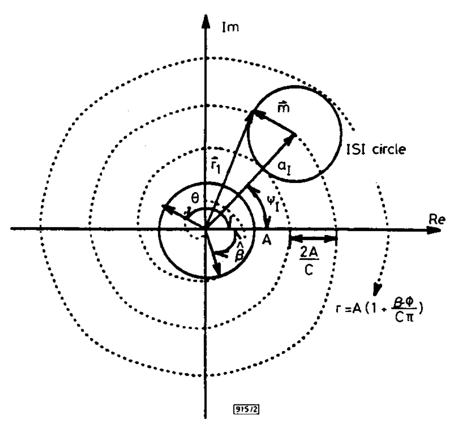

Fig. 2 *Phasors of* $Ae^{j\beta}$, $a_I e^{j\Psi_I}$ and $Ae^{j\Phi}$

Nonlinear phase precoding: Phase-shift keying (PSK) is used to demonstrate how the precoder works. The signal to be transmitted over $t \in [iT, iT + T]$ is represented as $\vec{s} = Ae^{j\beta}$, where T is the symbol interval, A is the constant envelope, β is the carrier phase carrying the transmitted information. After precoding, the actual transmitted signal is $\vec{m} \triangleq Ae^{j\theta}$. The ISI component of the received signal is represented as $\vec{u} \triangleq a_I e^{j\Psi_I}$, which is known to the transmitter according to channel characteristics and previously transmitted signals. If there is no fading on the direct path, the received signal is $\vec{r}_1 = r_1 e^{j\Phi_1} \triangleq Ae^{j\theta} + a_I e^{j\Psi_I} + n$, where n is the equivalent complex additive white Gaussian noise (AWGN) at baseband with zero mean and one-sided spectral density N_0. In the case of a non-minimum-phase fading channel, a predistorted signal with amplitude A cannot be found to completely equalise the channel so that the transmitted information can be correctly detected by the phase of the received signal. If we predistort the transmitted signal in such a way that we can establish a relation between the amplitude and phase of the received signal, then we can use both amplitude and phase to correctly detect the transmitted information. A spiral curve has the required characteristic, as shown in Fig. 2, which is described by

$$r = A\left(1 + \frac{\beta - \phi}{C\pi}\right) \tag{1}$$

The spiral curve is characterised by two parameters (β, C): the carrier phase β is the angle on the curve when $r = A$, and C determines the distance between any two points on the curve with 2π phase difference. Because it is desirable to transmit the signal with constant amplitude A, the transmitted signal should be on the circle centred at origin with radius A. In the absence of AWGN, the received signal is on the mentioned circle offset by ISI (called ISI circle, Fig. 2) denoted by

$$r = a_I\cos(\phi - \psi_I) \pm \sqrt{A^2 - a_I^2\sin^2(\phi - \psi_I)} \tag{2}$$

The root of [1, 2], $r_1e^{j\phi_1}$, is the received signal without AWGN. By subtracting $a_Ie^{j\psi_I}$ from $r_1e^{j\phi_1}$, we obtain the predistorted signal $Ae^{j\theta} = r_1e^{j\phi_1} - a^{j\psi_I}$. At the receiver, the spiral curve is determined from the amplitude r_1 and carrier phase ϕ_1. The carrier phase β can be detected according to

$$\hat{\beta} = \phi_1 + \left(\frac{r_1}{A} - 1\right)C\pi \tag{3}$$

which is the angle of the point on the spiral curve at $r = A$. If the first path signal experiences channel fading with a complex gain $a_0e^{j\psi_0}$, we need to modify eqn. 1 to

$$r = \frac{A}{a_0}\left(1 + \frac{\beta - \phi - \psi_0}{C\pi}\right) \tag{4}$$

The effect of $a_0e^{j\psi_0}$ should be taken into account in obtaining the precoded phase θ.

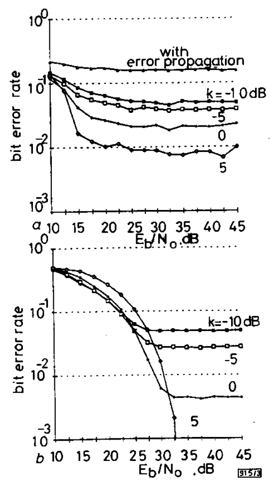

Fig. 3 *Bit error rate performance over a two-path Rician fading channel*

a DFE
b Nonlinear phase precoder

Performance evaluation: Fig. 3 shows the Monte Carlo simulation results of the BER performance using (i) DFE and (ii) the nonlinear phase precoder with $A = 1$ and $C = 4$, over a two-path equal-strength time-variant Rician fading channel with a normalised fading rate 0.5×10^{-3} and time delay T between the two paths. E_b is the ensemble average of the received signal energy per bit from both paths, and k is the power ratio of deterministic component to diffusive component of the Rician faded first path. We observe that:

(i) The BER using a DFE with detected symbol feedback is not acceptable at all due to the inherent error propagation of DFE.

(ii) Using the nonlinear precoder, there exists a BER floor due to precoding error in the case $a_0 << 1.0$, where the distance between any two points on the spiral curve with 2π phase difference is so large that no root exists for eqns. 2 and 34 and the ISI cannot be completely cancelled; however, the BER floor is significantly lower than that using a DFE with detected or correct decision feedback, especially when k is larger than –5dB.

(iii) At a low E_b/N_0 value (say, less than 25dB), if the precoder is used, the BER is worse than if a DFE with correct decision feedback were used, because the receiver is more sensitive to AWGN. The sensitivity varies with different C values. An adaptive algorithm for the optimal C value should be developed to further improve the system tranmission performance.

 11 October 1994
Electronics Letters Online No: 19941372

W. Zhuang and V. Huang (*Dept. of Elec. & Comp. Eng., Univ. of Waterloo, Waterloo, Ontario N2L 3G1, Canada*)

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Recursive algorithm for discrete sine transform with regular structure

Z. Wang, G.A. Jullien and W.C. Miller

Indexing terms: Discrete cosine transforms, Fast Fourier transforms

A new recursive algorithm for the discrete sine transform (DST) is derived, and shown to possess a very regular structure. There is no data shifting required. The only other existing recursive algorithm for the DST (Gupta and Rao, 1990) requires many data shifts and possesses an irregular structure.

Introduction: Since the introduction of the discrete sine transform (DST) by Jain [1], many algorithms have been proposed [2–4]. Two algorithms are presented in [4]. The first recursive algorithm reported in [4] is developed in a style similar to that of the Hou recursive algorithm for the discrete cosine transform (DCT) [5]. The structure of that algorithm is irregular, and requires ($N/2(\log_2 N - 2) + 1$) data shifts. For some applications, which require large length transformations, the larger number of data shifts may significantly increase the computation time; the irregularity is also inconvenient for both software and hardware solutions. The second DST algorithm in [4], represented by $L_2E_2C_2$, resembles the Lee algorithm for the DCT [6] [Note 1], and possesses the same disadvantage as the Lee FCT: it may become unstable for large length transformations because secant multiplication coefficients are used [5].

In this Letter, we derive a new recursive algorithm for the DST, which possesses a very regular structure and requires no data shifts. In addition, the multiplication coefficients required by our algorithm can be generated by a simple recursion and are arranged in a regular fashion.

Note 1: The algorithm for the DCT given in [4] is actually identical to the Lee FCT algorithm, and should not be considered a recursive algorithm because no recursive relation exists among input data or output coefficients. Accordingly, the second DST algorithm in [4] should not be considered a recursive algorithm either.