Fig. 3 Experimental apparatus for measuring binary error probability and AGC voltage at 1.5 GHz as a function of delay setting of adjustable GR line.

noise (14 dB) is added to the resultant signal to degrade it so that errors occur when the interference branch is removed. This is done so that a E_s/N_o ratio can be established from a known probability of bit error, P_e . That is, reference values for the bit error probability, P_e , and the signal level were established by disconnecting the interference branch at the line stretcher, terminating both unconnected points and then measuring the resulting P_e and AGC voltage. The P_e reference was about 3×10^{-6} yielding $E_s/N_o \approx 13$ dB.

In Fig. 4, we plot the observed and predicted binary error probabilities versus normalized round-trip delay, $2d/CT$, for two bit durations. Two sets of experimental P_e 's were recorded on Jan. 6 and Jan. 11, 1977. For about the 1st half of the first bit interval, the modulation phase of the direct and reflected rays is the same over at least half the bit interval, and the variation in P_e is caused by the constructive and destructive radio frequency phase interference. For the remaining segment of the 1st bit interval and succeeding bit intervals, the probability of bit error remains high (on the order of 10^{-3}).

CONCLUDING REMARKS

Observed and predicted binary error probabilities are presented for a channel suffering from intersymbol interference caused by multipath. It is encouraging to find how well existing theory predicts the qualitative and quantitative variation in binary error probability with round-trip delay for this deterministic form of multipath. Two noteworthy, albeit rather well known features of the binary error probabilities are: the high P_e 's versus multipath delay that persist throughout the entire 2nd bit interval and the oscillation in P_e versus multipath delay during the first bit interval. The error probability achieves a minimum near the point where the echo is in phase with the main signal, i.e., $2d = \lambda_o$. The actual minimum occurs at a value slightly less than this since for less delay there is more signal energy from the present symbol from the echo in the matched filter. Obviously, if all the echo energy from the present symbol is outside the matched filter the oscillation of the error probability will not occur.

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Fig. 4 Comparison of predicted and observed binary error probabilities versus delay for the 1.5 GHz indoor multipath experiment.

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Comments on "On Binary DPSK Detection"

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Abstract—This brief correspondence notes the equivalence between the optimum M -ary DPSK receiver given recently by Park¹ and another form of this receiver suggested earlier in the literature but not referenced in Park's paper.

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¹ J. H. Park, Jr., *IEEE Trans. Commun.*, vol. COM-26, pp. 484-486, Apr. 1978.

In the referenced paper [1], the author first presents the optimum M -ary DPSK receiver and then derives an expression for its error probability performance particularly for the binary case, i.e., $M = 2$. It should be noted that the optimum M -ary DPSK receiver has previously been given (see Figure 5-21 of [2]) and its error probability performance for all M derived (pp. 246-248 of [2]). Thus, rather than derive the error probability of Figure 1 of [1], it might be perhaps of more reader interest to demonstrate that indeed this optimum receiver is equivalent (forms its data decisions based on the same statistic) to Figure 5-21 of [2]. This is shown as follows: Figure 5-21 of [2] makes its decision by choosing that angle θ which satisfies

$$\theta \triangleq \min_i l_i = \min_i \left\{ \tan^{-1} \frac{X_k}{Y_k} - \tan^{-1} \frac{X_{k-1}}{Y_{k-1}} - \frac{2\pi i}{M} \right\} \quad (1)$$

where X_k and Y_k (see [1]) are the quadrature integrate-and-dump outputs corresponding to the k th bit transmitted. Combining the arctangents gives

$$\theta = \min_i \left\{ \tan^{-1} \left[\frac{X_k Y_{k-1} - X_{k-1} Y_k}{X_k X_{k-1} + Y_k Y_{k-1}} \right] - \frac{2\pi i}{M} \right\}. \quad (2)$$

Recognizing that

$$\min_i l_i = \max_i \{ \cos l_i \} \quad (3)$$

we get the equivalent relation

$$\begin{aligned} \theta &= \max_i \left[\cos \left\{ \tan^{-1} \left[\frac{X_k Y_{k-1} - X_{k-1} Y_k}{X_k X_{k-1} + Y_k Y_{k-1}} \right] - \frac{2\pi i}{M} \right\} \right] \\ &= \max_i \left[\frac{X_k X_{k-1} + Y_k Y_{k-1}}{R} \cos \frac{2\pi i}{M} \right. \\ &\quad \left. + \frac{X_k Y_{k-1} - X_{k-1} Y_k}{R} \sin \frac{2\pi i}{M} \right] \end{aligned} \quad (4)$$

where

$$R = \sqrt{(X_k Y_{k-1} - X_{k-1} Y_k)^2 + (X_k X_{k-1} + Y_k Y_{k-1})^2}. \quad (5)$$

Since R is not dependent on i , (4) simplifies to

$$\begin{aligned} \theta &= \max_i \left[(X_k X_{k-1} + Y_k Y_{k-1}) \cos \frac{2\pi i}{M} \right. \\ &\quad \left. + (X_k Y_{k-1} - X_{k-1} Y_k) \sin \frac{2\pi i}{M} \right] \end{aligned} \quad (6)$$

which agrees with the test statistic in (5) of [1]. (Q.E.D.)

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A Note on Measures of Voice Transmission Performance Used by the CCIR

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Abstract—The articulation index (AI) described in CCIR Report 526 as a measure of voice intelligibility cannot adequately represent the effects of interfering signals on voice intelligibility. The minimum interference threshold (MINIT) described in the same report as a measure of voice transmission performance is not a performance measure.

INTRODUCTION

The CCIR [1] has adopted the following two reports regarding the radiofrequency (RF) interference:

Report 525, Provisional signal-to-interference protection ratios required for spectrum utilization investigations; and

Report 526, Measures of voice transmission performance.

Among other concepts, Report 526 describes the articulation index (AI) and minimum interference threshold (MINIT), each as a measure of voice transmission performance. In its Table IV, Report 525 gives, for many combinations of various types of wanted signals and various types of interfering signals, values of signal-to-interference protection ratios both for the AI criterion and for the MINIT. Both reports are based on ECAC's degradation handbook [2], which is hereinafter referred to as the Handbook.

This note examines applicability of AI to RF interference problems and validity of MINIT. In the discussions that follow, we assume that the data presented in the Handbook are correct.

DISCUSSIONS ON THE USAGE OF AI

The ANSI standard for methods for calculating AI [3] states in its Section 5 that AI's adequately predict the effects of wide band, continuous spectrum noise and effects of bands of noise wider than 200 Hz in the audio band, but it does not mention the effects of undesirable line-spectrum components in the band. In many RF interference problems, one or more strong line-spectrum components appear in the audio band. A question may be raised, therefore, on the applicability of AI to RF interference problems.

This question can be answered with numerical data presented in the Handbook. The Handbook gives, for many combinations of wanted signal and interfering signal, many figures that contain curves for voice intelligibility versus signal-to-interference ratio (SIR). In each figure, the ordinate is doubly scaled with the AI and articulation score (AS) that is the percentage of words correctly understood. We read, from the curves given in the Handbook, values of the SIR that correspond to AS = 78% and 45% (i.e., protection ratios for the AS criterion). (According to the Handbook, these two AS values correspond to AI = 0.7 and 0.3, respectively, when the inter-

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