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*

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

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

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

Recognizing that

$$\min_i l_i = \max_i \{\cos l_i\} \tag{3}$$

we get the equivalent relation

$$\theta = \max_i \left[\cos \left\{ \tan^{-1} \left[\frac{X_k Y_{k-1} - X_{k-1} Y_k}{X_k X_{k-1} + Y_k Y_{k-1}} \right] - \frac{2\pi i}{M} \right\} \right]$$

$$= \max_i \left[\frac{X_k X_{k-1} + Y_k Y_{k-1}}{R} \cos \frac{2\pi i}{M} \right.$$

$$\left. + \frac{X_k Y_{k-1} - X_{k-1} Y_k}{R} \sin \frac{2\pi i}{M} \right] \tag{4}$$

where

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

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

$$\theta = \max_i \left[(X_k X_{k-1} + Y_k Y_{k-1}) \cos \frac{2\pi i}{M} \right.$$

$$\left. + (X_k Y_{k-1} - X_{k-1} Y_k) \sin \frac{2\pi i}{M} \right] \tag{6}$$

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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fering signal is white Gaussian noise.) We compare these protection ratios with protection ratios for AI = 0.7 and 0.3 (i.e., protection ratios for the AI criterion) that are tabulated in Table IV of Report 525. Table 1 of this note shows the differences in protection ratios in decibels between these two criteria, which can also be regarded as conversion factors for the protection ratios from the AI criterion to the AS criterion or vice versa. (In this table, symbols A, F, and P designate amplitude, frequency, and pulse modulation, respectively; numerals 0, 1, 3, and 9 that follow the above symbols designate no modulation, telegraphy without modulating tones, telephony, and modulation with a signal or signals that cannot be classified otherwise, respectively; symbol J designates single-sideband modulation with a suppressed carrier; and symbol N implies white Gaussian noise.) This table indicates that the conversion factors vary widely among various combinations of wanted signal and interfering signal; these factors vary in a range wider than 30 dB. Since the AS is the basic measure of voice intelligibility as stated in Report 526 and also in the Handbook, and since conversion factors of wide variability are required to convert the protection ratio values based on the AI criterion to meaningful protection ratio values based on the AS criterion, we must conclude that the AI cannot adequately represent the effects of interfering signals on voice intelligibility. We must also conclude that, unless other supporting evidences are presented, the protection ratio values for the AI criterion given in Table IV of Report 525 are meaningless numbers.

TABLE 1
DIFFERENCE IN SIGNAL-TO-INTERFERENCE PROTECTION RATIO IN dB BETWEEN THE AI CRITERION AND AS CRITERION

(Protection Ratio for AI = 0.7 Less Protection Ratio for AS = 78% in the Upper Row, and Protection Ratio for AI = 0.3 Less Protection Ratio for AS = 45% in the Lower Row.)

Wanted Signal \ Interfering Signal	A1	A3	A3J	F1	F3	F9	PO	N
A3	> 18 > 6	2 -3	7 -3	> 8 > 3	0 0	- -	>22 > 7	0 0
A3J	>23 >11	3 -11	1 -6	>24 > 7	< 3 -2	0 0	>23 >11	0 0
F3	> 5 > 0	– –	– –	>10 > 4	5 0	6 0	> 16 > 0	0 0
F9	>32 > 3	3 -3	– –	> 5 > 2	6 -1	0 0	> 0 > 0	0 0

DISCUSSIONS ON THE USE OF MINIT

In Report 526, the MINIT is defined as "the level at which the interference is first observed" in the presence of noise. Since a voice signal contains frequent pauses, presence of interference is very likely to be judged in these pauses. As a matter of fact, Report 526 states that "the test (for measuring the MINIT) can also be made without the presence of a desired signal." Thus, the MINIT is the level below which the interfering signal is buried in noise. The level of the interfering signal at the MINIT depends only on the level of noise but not on the level of the desired signal. Since the quality of a voice signal depends on the level of the desired signal as well as the levels of interfering signal and noise, and since the interfering-signal level at the MINIT is independent of the desired-signal level, the MINIT can represent neither a fixed quality of a voice signal nor a fixed grade of voice transmission performance. It is therefore concluded that the MINIT is not a performance measure.

To observe how the MINIT is used, we will quote the following statements from Report 525:

> The protection ratios are given for three performance levels and .... The threshold levels range from a minimum interference threshold (MINIT) to a maximum interference threshold (MAXIT).... The MINIT for a voice signal denotes the boundary between a region in which there is no interference and a region in which there is detectable interference, but no degradation to intelligibility. This also corresponds to a 1.0 Articulation Index (AI) score. For a voice signal a 0.7 AI score is used for the second threshold .... For a voice signal a 0.3 AI score is used for a MAXIT ....

These statements clearly indicate that the MINIT is used as a performance measure. Since what is not a performance measure is used as a performance measure, the portion of Report 525 that is concerned with the MINIT thus contains serious errors.

It is also clear from the definition of the MINIT that the value of signal-to-interference protection ratio at the MINIT can be changed arbitrarily without regard to performance level by assigning an arbitrary value to the signal-to-noise ratio (SNR). These arbitrary changes are actually done when Report 525 summarizes the Handbook; the Handbook gives protection ratio values at the MINIT for SNR = 10 dB and 25 dB, while Report 525 gives values for SNR = 35 dB. Therefore, the protection ratio values for the MINIT given in Table IV of Report 525 are arbitrary numbers.

In the Interim Meeting of CCIR Study Group 1 held in May 1976, the Study Group adopted some revisions on Report 525 and 526. Although the revised Reports cannot be official CCIR Reports until they are adopted by the next Plenary Assembly, these revisions are worth mentioning. Revised version of Report 526 clearly states that the MINIT is not a performance measure. The Study Group, therefore, has achieved a progress at this point. The same Report, however, continues to list the MINIT as a performance measure. Moreover, the revised version of Report 525 also continues to use the MINIT as a performance measure. Therefore, revised Reports 525 and 526 are as a whole more confusing than before.

CONCLUSIONS

Using the data given in the Handbook [2] that forms the basis for CCIR Reports 525 and 526 [1], we have examined applicability of AI that is described in Report 526 as a measure of voice intelligibility, with a negative result. We have also examined validity of MINIT that is described in the same report as a measure of voice transmission performance, also with a negative result. Based on these results, it is recommended

- that the AI not be used for representing the effects of interfering signals on voice intelligibility;
- that, when intelligibility is the primary concern, the AS criterion instead of the AI criterion be used for signal-to-interference protection ratio calculations;

- that the MINIT not be used as a measure of voice transmission performance for signal-to-interference protection ratio calculations;
- that efforts be made to establish a valid measure of high-quality voice transmission performance that will replace the MINIT; and finally
- that values of signal-to-interference protection ratio for voice wanted signals given in Table IV of CCIR Report 525 not be used until the report is revised as recommended above.

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