5i’

§ 3 Suppl´ement n^{o} 3 au d´ebut de cette page

4.1 *Introduction*

NTT has been studying an objective model for evaluating telephone transmission performance [39], [40], [41], [42]. This describes OPINE (Overall Performance Index model for Network Evaluation), focussing on practical use.

OPINE deals with transmission loss, circuit noise, room noise, attenuation/frequency distortion (fundamental factors), quantizing distortion, talker echo and sidetone. It models the auditory-psychological process of evaluation by human beings of telephone transmission performance based on these factors. It is therefore the second type of model according to the classification of § 2 (British Telecom). The model’s basic principle is the fact that evaluation of psychological factors (not physical factors) on the psychological scale is additive. The model is extended from the first revision to take additional physical factors into account.

OPINE was first constructed for fundamental factors in 1983 [39]. The opinion test data used for coefficient training and verification largely depend on the results of the experiment conducted at NTT ECL, Musashino in 1975. Its main purpose was to study the opinion score as a speech quality measure and a basis of telephone transmission standard. [40] and [43] describe the raw data. The experiment was of large scale with various factors taken into account, using an NTT 600-type telephone set.

4 **Overall Performance Index model for Network Evaluation (OPINE)** (contribution by NTT)

In 1985, opinion tests were conducted for quantizing distortion. A newer revision of the model that also dealt with quantizing distortion was formulated and verified [41].

Some further opinion tests for talker echo and sidetone were conducted in parallel [44], [45]. A study of the evaluation characteristics of talker echo and its interaction with loudness was undertaken later.

In 1986 revision 2.0 of OPINE was formulated [43] in which all the parameters were rewritten in terms of loudness rating (LR). This revision was improved and updated to 2.1. Improved points in revision 2.1 are these minor changes:

— Δf has been corrected to agree with that of Recommendation P.79,

— a trivial bug of the Fortran program in revision 2.0 has been eliminated.

While the model configuration was studied, the psychological characteristics of opinion evaluation were also investigated [46], using transmission loss and circuit noise as variables. The main conclusions were:

— the opinion score has good reproducibility if experimental design, subject type and other conditions are kept constant,

— the test condition range greatly affects the opinion score. The loss condition range especially affects the absolute opinion score.

In spite of the above conclusions, an absolute evaluation for a given network condition needs to be defined for practical use.

Therefore, we specify two classes of opinion tests:

— Class 1, in which the score reflects the mean value of network evaluation for general telephone customers;

— Class 2, which produces a relative score but is sensitive to a few given physical factors.

In the class 1 test, the purpose is to obtain an absolute opinion score. Therefore the range of test conditions should be similar to that for degradation in the present commercial network. The more factors taken into account in the opinion test, the closer the score comes to an absolute value. The number of subjects should exceed 60. The class 2 test, on the other hand, is used to study interaction among several factors. It is more practical but the score obtained is not absolute. For this test, it is desirable that the subject's occupation be connected with the subject of speech quality.

In formulating OPINE, we classified the opinion database in 1975 as the first class, and the rest as the second.

Opinion data executed after 1983 were mainly used for qualitative verification of the additive characteristics of evaluation on a psychological scale for different factors.

In extensions of OPINE, coefficients for newer factors were changed so that they fitted the results of the absolute score of the class 1 test of 1975.

4.2 *Outline of the model*

Five psychological factors affecting telephone speech quality were chosen on the basis of previous studies:

1) speech distortion for attenuation/frequency distortion,

2) effective loudness loss or excess in speech,

3) noisiness during speech intervals and non-speech intervals,

4) degradation caused by talker echo,

5) degradation caused by sidetone.

A PI (Performance Index) is also introduced for each of the above factors which indicates the psychological degradation degree. The MOS is estimated from the Overall Performance Index (OPI) which is obtained by summing up all PIs.

To calculate the PI for each factor, physical factors are obtained for loudness, distortion, etc., and each PI is transformed by an appropriate function. These functions are determined heuristically and the necessary constants are estimated from subjective data. The degree to which each factor

influences the evaluation is reflected by these constants. The conceptual block diagram of OPINE is shown in Figure 4-1. The model consists of four parts: 1) an overall electro-acoustic calculation, 2) hearing parameter derivation, 3) a performance index derivation and 4) an evaluation derivation. The numbers in the figure refer to the equation numbers listed in § 4.3.

4.3 *Configuration of OPINE*

All the symbols are classified into 5 types:

Type [A]: model parameters

Type [A-1]: constants or coefficients adopted from standards

Type [A-2]: constants or coefficients that OPINE accepted from results of other studies

Type [A-3]: estimated coefficients from the results of NTT's subjective tests

Type [B]: input variables of the section being described

Type [C]: OPINE's intermediate outputs of the section being described.

Figure 4-1, p.1

Input variables to the model and the values of model parameters are listed in § 4.4. In the following equations, C_j (j =1,13) denote constants ([A-3]-type). The suffix i denotes the 1/3 octave frequency band number. Relations among variables corresponding to each section are shown in Figures 4-3 through 4-10. The definition of the graphic symbols used in these figures is shown in Figure 4-2.

4.3.1 *Overall electro-acoustic calculation*

4.3.1.1 *Opinion equivalent white noise level of quantizing distortion*

The model expresses CODEC's subective evaluation as an opinion equivalent speech-to-speech correlated noise ($Q_{o\dp}$). Then the equivalent white noise level is acquired using the subjective opinion test results for MNR. If $A_{o\dp}$ of a certain CODEC or its tandem connection is known, it is possible to use the value as input. The various CODECs and $Q_{o\dp}$ adopted here are listed in Table 4-1.

H.T. [T11.3]

TABLE 4-1

Values of Q↓o↓p for PCM and ADPCM↓v

Transmission system	*Q*
PCM μ*-255, 8 bit*	*36.0*
MIC μ-255, 7	32.8
MIC μ-255, 6	27.7
MIC μ-255, 5	22.5
MIC μ-255, 4	16.7
ADPCM v	29.2

Table 4-1 [T11.3], p.

where

(+) is the power summation operation

Type [B] symbols

$Q_{o\dp}$ is the opinion equivalent speech-to-speech correlated noise ration (dB)

V_C is the circuit noise level at the input to the receiving local telephone circuit (dBmp)

OLR is the overall loudness rating of the telephone system being considered (dB)

RLR is the receive loudness rating of the telephone system being considered (dB)

Type [C] symbols

$V_{W\do\dp}$ is the opinion (PI) equivalent white noise level at the input to the receiving local telephone circuit. (dBmp)

PI_Q is the PI for quantizing distortion.

$V_{C\dQ}$ is the equivalent circuit noise level when both circuit noise and quantizing distortion are present. (dBmp)

Note — When the digital system is not considered in a test condition, equations (4-1) and (4-2) are not necessary, and $V_{W\do\dp}$ is set to an arbitrary low level, such as —100, in equation (4-3).

4.3.1.2 *Speech level and total noise level at an ERP* (see also Annex C)

Where:

(+) power summation operation

Type [A-1] Symbols

$B_{S\backslash \mathrm{d}i}$ is the spectrum density of speech referred to an MRP (dB rel 20 μPa/Hz)

Δf_i is the width of ISO preferred 1/3 octave frequency band (Hz)

Type [A-2] Symbols

$B_{P\backslash \mathrm{d}i}$ is the peak spectrum level of speech referred to an MRP (dB rel 20 μpa/Hz)

X_i is the hearing threshold for the continuous sound referred to an ERP (dB rel 20 μPa/Hz)

B_{0i} is the pure tone audibility threshold (dB rel 20 μPa/Hz)

K_i is the critical bandwidth (dB)

$L_{R\backslash \mathrm{d}N\backslash \mathrm{d}E\backslash \mathrm{d}i}$ is the leakage transmission loss at a listener's ERP (dB)

Type [B] symbols

$L_{M\backslash \mathrm{d}E\backslash \mathrm{d}i}$ is the overall mouth-to-ear loss (dB)

$S_{J\backslash \mathrm{d}E\backslash \mathrm{d}i}$ is the receiving sensitivity of a local telephone circuit from the electrical input to an ERP (dB rel Pa/V)

$B_{R\backslash \mathrm{d}N\backslash \mathrm{d}i}$ is the room noise spectrum density (dB rel 20 μPa/Hz).

A-weighted evaluation of $B_{R\backslash \mathrm{d}N\backslash \mathrm{d}i}$ becomes R_N (dBA)

$L_{R\backslash \mathrm{d}N\backslash \mathrm{d}S\backslash \mathrm{d}T\backslash \mathrm{d}i}$ is the sidetone transmission loss from an MRP to an ERP (dB)

$V_{C\backslash \mathrm{d}Q\backslash \mathrm{d}i}$ is the equivalent circuit noise level when both circuit noise and quantizing distortion are present (dBV/Hz)

Psophometric weighted evaluation of $V_{C\backslash \mathrm{d}Q\backslash \mathrm{d}i}$ becomes $V_{C\backslash \mathrm{d}Q}$

Type [C] symbols

S_i is the band spectrum level of speech at an ERP (dB rel 20 μPa/Hz)

$S_{P\backslash \mathrm{d}i}$ is the peak spectrum level of speech referred to an ERP (dB rel 20 μPa/Hz)

N_i is the total band noise level at an ERP (dB rel 20 μPa)

$N_{C\backslash dQ\backslash di}$ is the noise level caused by stationary circuit noise and quantizing distortion at an ERP (dB rel 20 μPa/Hz)

$N'_{C\backslash dQ\backslash di}$ is the band level of $N_{C\backslash dQ\backslash di}$ (dB rel 20 μPa)

$N_{R\backslash dN\backslash dS\backslash dT\backslash di}$ is the noise sidetone level caused by room noise at an ERP (dB rel 20 μPa/Hz)

$N_{R\backslash dN\backslash dE\backslash di}$ is the room roise level via earcap leakage (dB rel 20 μPa/Hz).

4.3.2 *Derivation of hearing parameters and performance index (PI)*

4.3.2.1 PI_E

where:

max is a suffix which denotes maximum value within the passing bands

Type [A-1] symbols

G_i is the ratio of loudness for frequency band *i* in a lossless system to total loudness (loudness function)

Δf_i is the width of the *i* th frequency band (Hz)

m is the ear's exponential coefficient (= 0.175)

M is the number of partitioned bands (= 19)

Type [A-3] symbols

λ_0 is the optimum loudness at ERP

C is a constant. Value of C is not needed since C is cancelled in equation (4-15)

Type [B] symbols

$L_{M\backslash dE\backslash di}$ is the transmission loss-frequency characteristic from MRP to ERP (dB)

Type [C] symbols

$PI_{E\backslash dL}$ PI on loundess in both the absence and presence of noise

λ_E is the effective loudness at ERP taking the effect of noise into account

b_n is the equivalent loudness loss in the presence of noise (dB)

e_n is the maximum sensation peak level of speech (dB).

4.3.2.2 *Expression of* PI_E

Equation (4-15) is theoretically expressed in terms of LR. The derivation of equation (4-16) from equation (4-15) is shown in Annex E.

where:

Type [A-3] symbol

OLR_0 is the overall loudness rating value at which the telephone system supplies the optimum loudness (dB)

Type [B] symbol

OLR overall loudness rating of the telephone system being considered (dB).

4.3.2.3 *PI*

where:

Type [A-1] symbol

A_i is the weight for A-characteristic at frequency band *i* (dB)

Type [A-3] symbols

$N_{t\backslash dh}$ is the noise threshold (dB rel 20 μPa)

n is the exponent

Type [B] symbol

$N'_{C\backslash dQ\backslash di}$ (see § 4.3.1.2)

Type [C] symbols

$PI_{I\backslash dN}$ is the PI for idle circuit (non-speech interval) noisiness.

N'_i is the level above the noise threshold (dB).

Type [A-3] symbol

$SNR_{t\backslash dh}$ is the threshold below which the signal-to-noise ratio has no effect on the evaluation (dB)

Type [B] symbols

S_i (see § 4.3.1.2)

N_i (see § 4.3.1.2)

Type [C] symbols

$PI_{S\backslash dN}$ is the *PI* for speech interval noisiness.

SNR is the Signal-to-noise ratio at an ERP (dB).

4.3.2.4 PI_A

where:

g_i is the conversion function from the speech power spectrum into a loudness level by equal-loudness curve (from [48])

x_i is the arbitrary band speech level (dB rel 20 μPa)

Type [A-1] symbols

M is the number of partitioned bands (= 19)

a_i are the parameters for converting to loudness level (in phones); they are a function of frequency

Type [A-2] symbol

M_s is the band number in which 1 kHz is contained (= 11)

Type [A3] symbol

$L_{t\backslash dh}$ is the loudness threshold (phon)

$\Lambda_{t\backslash dh}$ is the threshold of Λi (phon)

Type [B] symbol

d_i is the relative loss caused by attenuation/frequency distortion between junctions (dB)

It is 0 dB at 800 Hz. $S + d$ represents hypothetical band speech level at an ERP without attenuation/frequency distortion (reference speech)

Type [C] symbols

Λ_i is the difference between reference speech and distorted speech (phon)

Λ_l is the loudness level converted from reference speech (phon)

Λ_d is the loudnes level converted from speech with both loss and band limitation (phon)

D_u is the distance between Λ_l and Λ_d above 1 kHz

D_l is the distance between Λ_l and Λ_d below 1 kHz

$PI_{A\backslash dD}$ is the PI for attenuation/frequency distortion.

4.3.2.5 PI_E

where:

Type [B] symbols

E is the talker echo LR (dB)

D is the delay time of talker echo (msec)

Type [C] symbols

$PI_{E\backslash dC}$ is the performance index on talker echo

E_0 is the critical talker echo LR (dB).

4.3.2.6 PI_S

where:

Type [A-3] symbol

St_0 is the critical STMR (dB)

Type [B] symbol

St is the STMR (sidetone masking rating) (dB)

Type [C] symbol

$PI_{S\backslash dT}$ is the performance index on sidetone.

4.3.3 *Evaluation derivation* (see also Annex D)

where:

Type [A-3] symbol

P_0 is *P* with no degradation.

Type [C] symbols

OPI is the overall performance index

P is the mean overall evaluation on this psychological scale

where:

Type [A-3] symbol

σ is the standard deviation of normal distribution of *P* and *OPI*

Type [C] symbols

MOS is the mean opinion score ranging from 0 to 4

p_k is the ratio of evaluation category *k* to all the categories.

Equation (4-35) is calculated using the standard normal distribution table. The derivation of this equation from equation (4-34) is shown in Annex F.

Equations (4-34) and (4-35) are the adaptation of the model in [49].

4.4 *Symbol types and values*

Input variables to the model are listed in Table 4-2. $L_{M\backslash dE}$ and *STMR* can be calculated in advance using the method described in Recommendation P.79.

Values of a_i, b_i and c_i ([A-1]-type) are shown in Table 4-3. Values of other model parameters ([A-1]- and [A-2]-type parameters) are shown in Table 4-4. Values of estimated constants or coefficients from the subjective test results ([A-3]-type parameters) are shown in Table 4-5.

H.T. [T12.3]

TABLE 4-2

Input variables to the model

Symbols	Definition
V	*See § 4.3.1.1*
Q	*See § 4.3.1.1*
OLR	{
See §§ 4.3.1.1, 4.3.2.2	
}	
RLR	See § 4.3.1.1
S_{MJi}	{
Mouth to junction loss (dB rel V/Pa)	
}	
S_{JEi}	See § 4.3.1.2
L	{
Junction to junction loss at 800 Hz (dB)	
}	
d	*See § 4.3.2.4*
L_{MEi}	See § 4.3.1.2
R	*See § 4.3.1.2*
L_{RNSTi}	See § 4.3.1.2
E	See § 4.3.2.5
D	See § 4.3.2.5
L_{MESTi}	{
Mouth to ear sidetone loss (dB)	
}	
St	See § 4.3.2.6

Note 1 $L_{MEi} = -S_{MJi} - S_{JEi} + (L + d)$.

Note 2 *St*
| is calculated according to Recommendation P.79, § 8.

Note 3 S_{MJi} , *L*
| and L_{MEST}
| only necessary to calculate L_{MEi}
| and *St* .

Note 4 *R*
| *should be expanded* B_{RNi} .

Tableau 4-2 [T12.3], p.3

FIGURE 4-4, p.5

FIGURE 4-5, p.6

FIGURE 4-6, p.7

FIGURES 4-7 ET 4-8 A L'ITALIENNE COTE A COTE, p.10-11

18 *T (PI for sidetone)*

FIGURES 4-9 ET 4-10 A L'ITALIENNE COTE A COTE, p.10-11

H.T. [T13.3]

TABLEAU 4-3

Values of a↓i, b↓i and c↓i

(interpolated from [48])

No.	Frequency (Hz)	*a*	*b*	*c*
1	*100*	*—33.5*	*1.570*	*—0.00269*
2	*125*	*—25.7*	*1.500*	*—0.00258*
3	*160*	*—19.4*	*1.444*	*—0.00248*
4	*200*	*—14.7*	*1.404*	*—0.00242*
5	*250*	*—10.8*	*1.362*	*—0.00231*
6	*315*	*—7.4*	*1.314*	*—0.00214*
7	*400*	*—4.7*	*1.259*	*—0.00185*
8	*500*	*—3.0*	*1.205*	*—0.00151*
9	*630*	*—1.5*	*1.141*	*—0.00107*
10	*800*	*—0.5*	*1.064*	*—0.00050*
11	*1000*	*0.0*	*1.000*	*0.00000*
12	*1250*	*0.6*	*0.967*	*0.00028*
13	*1600*	*1.7*	*0.037*	*0.00071*
14	*2000*	*3.3*	*0.924*	*0.00100*
15	*2500*	*5.3*	*0.928*	*0.00118*
16	*3150*	*7.3*	*0.940*	*0.00119*
17	*4000*	*7.9*	*0.954*	*0.00098*
18	*5000*	*5.3*	*0.973*	*0.00059*
19	*6300*	*—2.6*	*1.028*	*0.00013*

Tableau 4-3 [T13.3], p.12

H.T. [T14.3]

TABLE 4-4

Model parameters

	No.	Frequency	Δ	*B*	*B*	*X*	L_{RNE}	10 log 1 0 *G*	*A*
Parameter type				*[A-1]*	*[A-2]*	*[A-2]*	*[A-2]*	*[A-1]*	*[A-1]*
Source				*Rec. P.51*	*B + 12*	*NTT 1968*	*NTT 1968*	*Rec. P.79*	*ISO*
		(Hz)	*(Hz)*	*(dB) 20 µPa/Hz*	*(dB) 20 µPa/Hz*	*(dB) 20 µPa/Hz*	*(dB)*	*(dB)*	*(dB)*
	1	100	22.4	57.2	69.2	11.0	0.0	—32.63	—19.1
	2	125	29.6	60.0	72.0	8.9	0.0	—29.12	—16.1
	3	160	37.5	62.1	74.1	5.5	0.0	—27.64	—13.4
	4	200	44.7	62.9	74.9	2.2	0.0	—28.46	—10.9
	5	250	57.0	63.0	75.0	0.0	0.0	—28.58	—8.6
	6	315	74.3	62.4	74.4	—3.0	0.7	—31.10	—6.6
	7	400	92.2	61.0	73.0	—6.0	0.0	—29.78	—4.8
	8	500	114.0	59.3	71.3	—8.0	0.0	—32.68	—3.2
	9	630	149.0	57.0	69.0	—9.5	2.2	—33.21	—1.9
	10	800	184.0	54.2	66.2	—10.3	8.5	—34.14	—0.8
	11	1000	224.0	51.4	63.4	—11.0	13.5	—35.33	0.0
	12	1250	296.0	48.5	60.5	—11.8	15.5	—37.90	0.6
	13	1600	375.0	45.2	57.2	—13.0	20.0	—38.41	1.0
	14	2000	447.0	42.2	54.2	—16.0	23.7	—41.25	1.2
	15	2500	570.0	39.4	51.4	—19.8	30.0	—41.71	1.3
	16	3150	743.0	36.8	48.8	—23.0	27.0	—45.80	1.2
	17	4000	922.0	34.5	46.5	—26.0	33.5	—43.50	1.0
	18	5000	1140.0	32.7	44.7	—27.0	41.0	—47.13	0.5
	19	6300	1490.0	31.4	43.4	—24.0	50.0	—48.27	—0.1

Note X (=B_0 — k) and L_{RNE} | can be input parameters.

Tableau 4-4 [T14.3], p.13

H.T. [T15.3]

TABLE 4-5

Values of estimated constants and coefficients

No.	Related section	Output	Symbol	Value
1	4.3.2.1 4.3.2.2	PI E L	{	
C				
1				
C				
2				
λ				
0/*c*				
OLR				
0				
}	{			
0.0475				
0.010				
0.780				
5.34				
}				
2	4.3.2.3	PI I N	{	
N				
n				
C				
3				
}	{			
33.0				
0.50				
0.012				
}				
3	4.3.2.3	PI S N	*SNR* *C* 4	{
7.5				
—0.005				
}				
4	4.3.2.4	PI A D	{	
L				
C				
5				
C				
6				
Λ				
}	*{*			
57.5				
0.043				
0.043				
15.0				
}				
5	*4.3.2.5*	*PI E C*	*{*	
C				
7				
C				
8				
C				
9				
C				
1				
0				
C				
1				
1				
C				
1				
2				
}	{			
13.69				
0.01				

26.4 2.65 14.00 24.6 }				
6 *C* 1 3 *ST* 0 }	4.3.2.6 0.00856 9.000	PI S T	{	
7	4.3.3.**6**	MOS	*P* 0 σ	3.558 0.730

Tableau 4-5 [T15.3], p.14

ANNEX A

(to Supplement No. 3 — ref. to § 1.1)

Opinion ratings of transmission impairments

A.1 *Introduction*

The figures in this annex illustrate the relative effect of typical transmission impairments on opinion ratings. They are based on the transmission rating models described above. The opinion ratings assume a five-category rating scale (excellent, good, fair, poor and bad or unsatisfactory) and the results are presented in terms of the percent of ratings which are good or better (good plus excellent) and poor or worse (poor plus bad). Three equations for the conversion from transmission rating to the

opinion ratings are described above in the text of the Supplement. The one which is used in this annex is representative of conversational test results reported to the CCITT by several Administrations during the Study Period 1973-1976.

A.2 *Overall loudness rating and circuit noise*

Opinion ratings for the combined effects of OLR (L'_e in dB) and circuit noise (N'_c in dBmp) are shown in Figures A-1 and A-2. The circuit noise is referred to a receiving system with an RLR of 0 dB. In these figures the circuit noise equivalent for room noise N'_{Rde} is —58.63 dBmp and the bandwidth/slope factor (k_{BW}) is 1; quantization noise, listener echo, talker echo and sidetone are not included.

A.3 *Quantization noise from PCM processes*

Opinion results for the effect of quantization noise from tandem 7 bit and 8 bit μ-law and A-law PCM processes are shown in Figures A-3 and A-4. These results assume an OLR (L'_e) of 16 dB and a circuit noise (N'_c) of —56 dBmp. Room noise, bandwidth/slope and sidetone assumptions are the same as for § A.2. The speech level at the output of a telephone set with a 0 dB SLR is assumed to be —10 VU.

A.4 *Bandwidth*

The effect on opinion rating as a function of bandwidth between frequencies having 10 dB of loss relative to 1000 Hz is shown in Figures A-5 and A-6. These results assume an OLR (L'_e) of 16 dB, a circuit noise (N'_c) of —56 dBmp, a circuit noise equivalent for room noise (N'_{Rde}) of —58.63 dBmp, and lower (S_l) and upper (S_u) slope factors of 2 and 3 respectively. Listener echo, talker echo and sidetone effects are not included.

A.5 *Listener echo*

The effect of listener echo on opinion ratings is illustrated in Figures A-7 and A-8. In these figures the opinion is plotted (from both the original and alternate models of the supplement) as a function of the weighted listener echo path loss (*WEPL*) in dB and round-trip listener echo path delay (D_L) in milliseconds. The curves were calculated assuming an OLR (L'_e) of 16 dB, a circuit noise (N'_c) of —56 dBmp , a circuit noise equivalent for room noise (N'_{Rde}) of —58.63 dBmp, and a bandwidth/slope factor of 1. Talker echo and sidetone effects are not included.

A.6 *Talker echo*

Opinion ratings for talker echo are presented in Figures A-9 and A-10 as a function of the OLR of the talker echo path (E) in dB and the round-trip talker echo path delay (D) in milliseconds. Again, the OLR (L'_e) was taken as 16 dB, the circuit noise (N'_c) as —56 dBmp, the circuit noise equivalent of room noise (N'_{Rde}) as —58.63 dBmp and the bandwidth/slope factor as 1. Listener echo and sidetone effects are not included.

A.7 *Sidetone*

Opinion ratings for sidetone are presented in Figures A-11 and A-12 in terms of the sidetone path loss (*STMR*) in dB and the sidetone response shape in dB/octave. For these curves, impairment levels were selected to provide a constant R_{LN} value typical of toll calls in North America and a range of R_E values which might be encountered on toll calls in North America.

Figure A-1, p.15

Figure A-2, p.

Figure A-3, p.17

Figure A-4, p.18

Figure A-5, p.19

Figure A-6, p.20

Figure A-7, p.21

Figure A-8, p.22

Figure A-9, p.23

Figure A-10, p.24

Figure A-11, p.25

Figure A-12, p.26

ANNEX B
(to Supplement No. 3 — ref. to § 2.9)

Calculated transmission performance of telephone networks

B.1 *Introduction*

This annex is intended to give examples of results from the subjective model which is incorporated in the BT CATNAP (Computer-Aided Telephone Network Assessment Program) program. CATNAP comprises this model and a transmission calculation section which enables elements of a connection to be entered as readily identifiable items, e.g. lengths of cable, feed bridges etc. These results are examples of calculations for various ‘‘hypothetical reference connections’’ (HRCs) which might arise in the network or would be of use to planners.

The loudness ratings quoted are calculated according to Recommendation P.79, using the frequency bands from 200 Hz to 4 kHz. The opinion scores, $Y_{L\backslash dE}$ and Y_C, are on a scale of 0 to 4, representing the listening effort and conversation opinion scales (see Supplement No. 2). The values of line current shown with the results are determined by the program which decides from the characteristics of the local telephone system which of a number of standard line currents is appropriate, and hence which values of the telephone instrument characteristics should be used. The program also gives speech levels for controlled talking conditions (V_L) and under conversational conditions (V_C). These and the loudness ratings are referred to the interfaces (NI and FI) shown in the figures below.

These results are for the model as it stands at present (1983 version). Research is continuing to improve the correlation of calculated and experimental results, so the model is liable to modification.

B.2 *HRC 1 — Own exchange call* | see Figure B-1)

This is a symmetrical connection, with average length customers’ lines. The sidetone suppression is fairly good, and room noise and circuit noise levels are low. The conversation opinion score is good, but the small overall loss means that the connection is louder than preferred. A slightly quieter connection would give a better opinion score.

B.3 *HRC 2 — Limiting national call* | see Figure B-2)

These two HRCs are both symmetrical and comprise BT limiting local lines of 1000Ω/10 dB, 4.5 dB local junctions and two 4-wire junctions each with 3.5 dB loss, which are the limits set by the BT transmission plan (given in [29]).

HRC 2 (a) uses 0.5 mm copper local lines, which provide much better sidetone matching than the 0.9 mm copper lines of HRC 2 (b). The change in sidetone level (> | 0 dB) causes a drop in the conversation opinion score from 1.9 to 0.8 (from fair to poor).

B.4 *HRC 3 — Long distance call with a PCM junction* | see Figure B-3)

The overall loss of this connection (OLR = 13.4 dB) is much less than for HRC 2. The local lines are average length of 0.5 mm copper which give reasonably good sidetone matching, and there is now only one local junction. This is a 4-wire 3 dB PCM junction. This is entered as a single item, characterised by the terminating and balance impedances of the 2/4-wire terminating sets, the matched loss in each direction and the phase delay round the loop. Quantizing noise is negligible for the input speech levels calculated by CATNAP for this connection.

The connection is symmetrical in transmission loss but a small difference in the sidetone level has given slightly different conversation opinion scores at the two ends.

B.5 *HRC 4 — Asymmetry of transmission loss* | see Figure B-4)

A number of calculations have been done for this HRC to show the effect of varying the degree of asymmetry. The curves shown are not fitted curves, but simply join the marked points on the graph. They show the effect on the conversation opinion score and conversational speech voltage of varying the transmission loss in one direction only (from near end to far end). The loss from far to near is kept constant, so the opinion of the near end customer is much less affected. It is suspected that the speech voltage curves are too divergent and further research is needed in this area, but the opinion curves show similar trends to the results produced by Boeryd [30].

The sidetone level was virtually unaffected by the change in transmission loss.

B.6 *HRC 5 — Effect of room noise* | see Figure B-5)

The calculations done for this HRC demonstrate the effect of changing the level of room noise for a customer with a loud sidetone path (near end) and one with a quiet sidetone path (far end). As for HRC 4, the computed points are simply joined to form the line.

B.7 *HRC 6 — Effect of circuit noise and bandlimiting* | see Figure B-6)

This is a connection using 4-wire reference telephones, enabling sidetone to be controlled. The STMR is kept at 20 dB, at which level most customers would not detect it.

Such a connection can be used to investigate the effects of particular transmission impairments varied independently. Here it has been used to demonstrate the effect on the listening effort and conversation opinion scores of the level of injected circuit noise and band limiting (lowpass) over a range of losses likely to occur in telephone networks.

As for the previous curves the computed points are simply joined to form a line.

B.8 *HRC 7 — Multiple calculations with random selection of items*
| see Figure B-7)

CATNAP is intended to help assess telephone network proposals rather than single connections. The program can perform multiple calculations on a group of connections or on a single connection with random selection of elements from a database.

Here random selection is made of the customers’ lines out of a database derived from a survey of 1800 existing lines. This enables the performance of a particular element to be tested for a range of conditions which would arise in the actual network. Since the survey reflects the distribution of lengths and gauges in the actual network, this method of assessment gives a more accurate picture of the performance in the existing network.

For this example only a few calculations have been done to demonstrate the facility and so the results have been printed. This is not practical for large numbers of calculations, when the results are stored and can be processed as desired, e.g. by plotting the distribution or by statistical analysis.

The line number and radial distance have been given for both ends of each calculation.

B.9 *HRC 8 — Example of the use of CATNAP to meet a design criterion*
| see Figure B-8)

This is intended to give an example of the use of CATNAP in the design of individual network components to meet design targets.

With the introduction of electronic telephones the designer has a freer choice of values for the telephone instrument characteristics, e.g. the value of the line impedance which must be connected to the telephone instrument to give full sidetone suppression ($Z_{s\backslash do}$).

An iterative procedure can lead to preferred values for $Z_{s\backslash do}$. As examples, calculations have been done for a standard BT 706 and a 706 with some trial values for $Z_{s\backslash do}$ on BT limiting lengths of local copper cable of standard gauges, and an average length of 0.5 mm cable. For one of the trial sets of values which looks possible from these results and for a standard 706 instrument, a set of 40 calculations was done with random selection of local lines from the database of 1800 used for HRC 7. These results are given in terms of the mean and standard deviation of the distribution of STMRs. From this it can be seen that the trial values do give a better performance on

average, although the performance is worse on 0.63 mm and 0.9 mm limiting lines, since these are less common in the local network than 0.5 mm.

As a design tool, the program could be used further to verify the improvement in performance, to check the effects of tolerances and to consider possible improvements to these values.

B.10 *HRC 9 — Effect of varying line length* | see Figure B-9)

This HRC is identical to HRC 2 except for the gauge of cable. In this case 0.63 mm copper cable is used. Its length is varied from zero to 10 km, which is beyond the BT limiting length (7.2 km).

The results are shown as curves of conversation opinion score, OLR and conversational speech voltage against line length. As before, the computed points are simply joined to form a line.

The calculations on this HRC have been included to demonstrate the ‘‘inverse’’ use of CATNAP. The limits on OLR are known (from the transmission plan) and so these runs could be used to show what range of cable lengths are acceptable. The facility for calculating the performance in terms of conversation opinion score makes it possible to specify performance limits in terms of this, which is closer to the real performance than limits set in terms of loudness ratings.

Figure B-1, p.27

Figure B-2, p.28

Figure B-3, p.29

Figure B-4, p.30

Figure B-5, p.31

Figure B-6, p.32

Figure B-7, p.33

Figure B-8, p.34

H.T. [T16.3]

TABLE B-1

Values of STMR (dB) for specified lines (copper conudctors)

Z	*1.6 km 0.5 mm (median)*	6 km 0.5 mm	3.7 km 0.4 mm	7.2 km 0.63 mm	10 km 0.9 mm
		(limiting)			
706	*9.9*	*15.7*	*7.2*	*7.5*	*0.0*
{ *Conjugate of input Z* }	1.8	1.1	0.6	—0.2	—0.6
600 Ω	6.6	—0.8	—1.2	—2.0	—3.0
Suggested values	10.2	13.4	13.8	4.4	—1.3

Tableau [B-1] [T16.3], p35

H.T. [T17.3]

TABLE B-2

Distribution of STMR for a sample of 40 lines for a Standard 706
and the suggested values of
Z

Z	*Mean*	*Standard deviation*	*Maximum value*	*Minimum value*
706	*8.3*	± | *.5*	*14.1*	*3.8*
Suggested values	*9.4*	± | *.1*	*17.9*	*4.2*

Tableau B-2 [T17.3], p.36

Figure B-9, p.

ANNEX C
(to Supplement No. 3 — ref. to § 4.3.1.2)

Noise spectrum calculation

Expansion from the scalar value of noise to the spectrum values of both room noise and circuit noise is necessary (see Figure 4-4). The spectrum value database of R_N(60 dBA) and V_c(—56.0 dBmp) is shown in Table C-1. The value of room noise is taken from Figure 2/P.45 [50] and Figure 1 of Supplement No. 13. V_c is a mixture of circuit noise and switching office noise. They are expressed by flat noise and —8 dB/octave noise, respectively. If only a scalar noise level is known as a test condition,

and its spectrum value is not known, then a mixed noise spectrum is used in OPINE in which —8 dB octave noise is 10 dB lower than flat noise. Moreover, SRAEN characteristics are added to the flat noise characteristics.

H.T. [T18.3]
TABLE C-1
Noise spectrum value used in OPINE

R | = 60 dBA	*V* | = —56.0 dBmp				
No. *V* *CQi* | = *V* flat (+) *V* —8/oct }	*Frequency*	B_{RNi}	V_{flat} + SRAEN	$V_{—8/oct}$	{
	(Hz)	(dB) 20 µPa/Hz	(dBV/Hz)	(dBV/Hz)	(dBV/Hz)
1	100	42.07	—112.91	—75.25	—75.25
2	125	40.67	—102.61	—77.95	—77.93
3	160	39.07	—98.11	—80.55	—80.47
4	200	37.37	—96.81	—83.25	—83.06
5	250	35.87	—95.21	—85.95	—85.46
6	315	34.37	—93.31	—88.55	—87.29
7	400	32.87	—92.41	—91.25	—88.78
8	500	31.17	—91.91	—93.85	—89.76
9	630	29.57	—91.51	—96.55	—90.32
10	800	27.87	—91.21	—99.25	—90.57
11	1000	26.37	—91.21	—101.95	—90.86
12	1250	24.77	—91.21	—104.55	—91.01
13	1600	23.07	—91.11	—107.25	—91.00
14	2000	21.37	—91.01	—109.95	—90.95
15	2500	19.57	—91.01	—112.55	—90.98
16	3150	17.37	—91.21	—115.25	—91.19
17	4000	14.87	—178.71	—117.95	—117.95
18	5000	12.17	—291.21	—120.55	—120.55
19	6300	9.37	—291.21	—123.25	—123.25

Table C-1 [T18.3], p.

ANNEX D
(to Supplement No. 3 — ref. to § 4.3.3)

MDS calculation examples

The test condition with an NTT 600 type telephone and a 0.4 mm, 7 dB line as a local telephone circuit (LTC) is considered here. Input data concerning the LTC is shown in Table D-1. In this connection, SLR = 6.6 dB, and RLR = —3.8 dB. The test conditions and calculated results for fundamental factors are shown in Table D-2.

The output of the overall electro-acoustic calculation (§ 4.3.1) for test condition No. 11 in Table D-2 is shown in Figure D-1, where OLR is 6.4 dB.

H.T. [T19.3]
TABLE D-1
Local telephone circuit sensitivity
(NTT 600-type telephone set with a 0.4 mm, 7 dB line)

No.	Frequency	S_{MJi}	S_{JEi}	L_{MESTi}	L_{RNSTi}
	(Hz)	(dB) rel V/Pa	(dB) rel Pa/V	(dB)	(dB)
1	100	—22.3	—40.0	5.3	28.6
2	125	—25.1	—2.7	6.7	26.3
3	160	—23.8	2.5	5.0	20.8
4	200	—18.8	7.3	2.3	14.1
5	250	—14.4	11.3	—3.0	5.6
6	315	—12.3	14.6	—6.4	—1.3
7	400	—12.5	15.9	—5.6	—1.8
8	500	—12.6	15.7	—3.6	—0.3
9	630	—12.3	14.9	—2.1	2.8
10	800	—11.9	14.4	—0.4	3.9
11	1000	—11.6	14.5	0.1	3.4
12	1250	—12.0	14.8	0.0	3.1
13	1600	—12.0	14.1	0.1	0.1
14	2000	—9.8	14.4	—3.3	—2.1
15	2500	—10.0	16.2	—5.0	3.4
16	3150	—11.0	11.5	2.7	15.0
17	4000	—16.8	8.9	11.1	22.3
18	5000	—27.9	—30.0	28.1	35.1
19	6300	—32.0	—30.0	32.7	35.3

Tableau D-1 [T19.3], p.39

H.T. [T20.3]

TABLE D-2

Example of estimated results for fundamental factors by OPINE

{ Test conditions (STMR = 7.1 dB) }	Conversion to OPINE input	Output

No. Frequency characteristic (see Table D-3) }	Noise OLR (dB) OLR (dB)	R N (dBA) L (dB)	Circuit noise (dBmp) V C (dBmp)	Switching noise (dBmp) PI E L	{ PI N	PI A D	PI S T	OPI
1	—3.8	0			1	—3.6	—7.3	—95.1
2	1.2	0			1	1.4	—2.3	—95.1
3	6.2	0			1	6.4	2.7	—95.1
4	11.2	0			1	11.4	7.7	—95.1
5	16.2	0			1	16.4	12.7	—95.1
6	21.2	0			1	21.4	17.7	—95.1
7	26.2	0			1	26.4	22.7	—95.1
8	31.2	0			1	31.4	27.7	—95.1
9	—3.8	60	—56.9	—62.2	1	—3.6	—7.3	—55.8
10	1.2	60	—56.9	—62.2	1	1.4	—2.3	—55.8
11	6.2	60	—56.9	—62.2	1	6.4	2.7	—55.8
12	11.2	60	—56.9	—62.2	1	11.4	7.7	—55.8
13	16.2	60	—56.9	—62.2	1	16.4	12.7	—55.8
14	21.2	60	—56.9	—62.2	1	21.4	17.7	—55.8
15	26.2	60	—56.9	—62.2	1	26.4	22.7	—55.8
16	31.2	60	—56.9	—62.2	1	31.4	27.7	—55.8
17	1.2	60	—56.9		1	1.4	—2.3	—57.0
18	11.2	60	—56.9		1	11.4	7.7	—57.0
19	21.2	60	—56.9		1	21.4	17.7	—57.0
20	31.2	60	—56.9		1	31.4	27.7	—57.0
21	1.2	50	—56.9	—62.2	1	1.4	—2.3	—55.8
22	11.2	50	—56.9	—62.2	1	11.4	7.7	—55.8
23	21.2	50	—56.9	—62.2	1	21.4	17.7	—55.8
24	31.2	50	—56.9	—62.2	1	31.4	27.7	—55.8
25	1.2	45	—68.2	—68.2	1	1.4	—2.3	—65.2
26	13.2	45	—68.2	—68.2	1	13.4	9.7	—65.2
27	26.2	45	—68.2	—68.2	1	26.4	22.7	—65.2
28	1.2	45	—63.8	—68.2	1	1.4	—2.3	—62.5
29	13.2	45	—63.8	—68.2	1	13.4	9.7	—62.5
30	26.2	45	—63.8	—68.2	1	26.4	22.7	—62.5
31	2.2	60	—56.9	—62.2	3	2.5	—2.4	—55.8
32	12.2	60	—56.9	—62.2	3	12.5	7.6	—55.8
33	22.2	60	—56.9	—62.2	3	22.5	17.6	—55.8
34	32.2	60	—56.9	—62.2	3	32.5	27.6	—55.8
35	4.1	60	—56.9	—62.2	7	5.1	—2.3	—55.8
36	14.1	60	—56.9	—62.2	7	15.1	7.7	—55.8
37	24.1	60	—56.9	—62.2	7	25.1	17.7	—55.8
38	34.1	60	—56.9	—62.2	7	35.1	27.7	—55.8

Tableau D-2 [T20.3], p.40

H.T. [T21.3]
TABLE D-3
Attenuation/frequency characteristics used in Table D-2

Frequency	1	2	3
. (Hz)	SRAEN (dB)	(Note 1) (dB)	(Note 2) (dB)
100	21.7	40.0	76.0
125	11.4	32.0	60.0
160	6.9	23.0	47.0
200	5.6	17.2	36.0
250	4.0	12.0	24.5
315	2.1	6.5	15.0
400	1.2	2.5	7.0
500	0.7	1.0	2.5
630	0.3	0.5	0.5
800	0.0	0.0	0.0
1000	0.0	—0.1	0.0
1250	0.0	—0.1	0.0
1600	—0.1	—0.3	0.2
2000	—0.2	—0.1	0.9
2500	—0.2	0.5	2.5
3150	0.0	4.0	9.0
4000	87.5	12.5	19.5
5000	200.0	22.0	30.0
6300	200.0	32.0	41.0

Note 1 — Three 4-wire circuit chains, 50% limit characteristics.

Note 2 — Seven 4-wire circuit chains, 95.5% limit characteristics.

Tableau D-3 [T21.3], p.41

Figure D-1, p.42

ANNEX E
(to Supplement No. 3 — ref. to § 4.3.2.2)

Derivation of equation (4-16)

In employing equations (4-15) and (4-16), a constant is necessary for each, that is λ_0/C for (4-15) and OLR_0 for (4-16). Adaptation of the values in Table 4-5 allows a 0.004 error for two different $PI_{E\backslash dL}$ calculations. This error, however, does not cause further errors in subsequent calculations.

ANNEX F

(to Supplement No. 3 — ref. to § 4.3.3)

Psychological evaluation model

This Annex gives a detailed derivation of equations (4-34) and (4-35). The model is a complete adaptation of [49].

F.1 *Psychological model for evaluation*

According to the model in reference [49], an evaluation value for a test condition on a psychological continuum is shown in Figure F-1. p_K is defined on page 10 of the reference, and is the probability of voting K as an opinion score for a test condition. The correspondences of opinion scores to ranges in the psychological continuum are:

Continuum range Opinion score — ∞ 0.5 0 0.5 1.5 1 1.5 2.5 2 2.5 3.5 3 3.5 ∞ 4

Figure F-1, p.

These assumptions satisfy the following equation:

which is the same as equation (4-34).

F.2 *Derivation of equation (4-35) from equation (4-34)*

The cumulative probability of N (μ, σ | u2) is expressed using a standard normal distribution function as follows:

By changing the multiplication into a repetition of additions, and by changing the association (combination) of addition, equation (F-3) becomes:

Replacement of μ by *P* results in equation (4-35), which then enables the use of a standard normal distribution table.

APPENDIX I

(to Supplement No. 3 — reference to § 3.2.2)

```
10  PRINT ‘‘CALCULATION OF INFORMATION INDEX FOR CODECS AND MNRU’’

20  REM New frequency weighting, Ti from BOSQUET, new equivalence with MNRU
30  REM PROGRAM ICQSKBE2, BAS, June 1987, written in MF BASIC
40  INPUT ‘‘SYSTEM’’; S$
50  INPUT ‘‘MOS’’; Y$
60  INPUT ‘‘K1(0 for MNRU, 5.2 in other cases)=’’; K1
70  DATA .05457, 4.1, .04733, 5.6, .06682, 6.4, .07497, 6.9, .06546, 7.4, .06622, 7.8, .05585, 8, .054, 8, .05273, 8.2,     .05117, 8.2
80  DATA .04517, 8.2, .04706, 8.2, .05073, 8.2, .05561, 8.2, .0631, 8.2, 06886, 8.1
90  INPUT ‘‘QSEG over the band—QP=d(0 for MNRU and PCM)’’; SM
100 REM calculation for codecs (for MNRU if K1=d=0)
110 FOR J=1 to 16
120 PRINT ‘‘Qseg over the band No’’; J
130 INPUT QS
140 READ B, C
150 QC=QS+C
160 K2=1(1+EXP(—.159673*QC+.157246))
170 Q=K1+QC+K2*SM
180 V=3/(.1+10 | (—Q/10))
190 I=B*V
200 II=II+I
210 NEXT J
220 REM Display of results
230 PRINT S$,‘‘II=’’; II
240 LPRINT‘‘   ’’; S$; TAB(20); K1; TAB(30); SM; TAB(40); II; TAB(50); Y$; TAB(60)
250 END
```

APPENDIX II

(to Supplement No. 3 — reference to §§ 3.2.2 and 3.3)

```
10  PRINT ‘‘Calculation of Information Index for NTT 600 sets (7 dB line)’’

20  REM Program INT600E5 , written in MF Basic, September 1987
30  INPUT ‘‘Room noise,dBA=’’; RN
40  INPUT ‘‘STMR,dB=’’; STMR
50  INPUT ‘‘Circuit noise level (dBm, sign changed) at input to 0 dB     RLR end’’; I
60  ICNO=—I
70  INPUT ‘‘Listening (L) or conversation (C) or terminate (T)’’; A$
80  IP A$=‘‘T’’ GOTO 640
90  IF A$=‘‘C’’ GOTO 560
100 INPUT ‘‘Overall loudness rating (P79),dB=’’; OLR
110 LPRINT ‘‘   OLR=’’; OLR
120 GOSUB 730
130 REM Correction for excessive loudness
140 IF OLR>OPT GOTO 380
150 ×=2*OPT—OLR
160 GOTO 390
170 DIM FE (20), CN(20), ST(20), EL(20), BK(20), S(20), BJ(20), CJ(20), SRL(20), B1(20)
180 DATA —36.2,  —76.9,   —4.1,  32.4,  17.5, | 56.0, |
190 DATA —26.2,  —34.9,   —3 |  ,  31.2,  14.4, | 61.1, |
200 DATA —18.3,  —24 |  ,     .8,  29.5,  10 |  , | 62.5, |
210 DATA  —9.9,  —13.2,    5.6,  27.6,   5 |  , | 64.3, |
220 DATA  —2.1,   —3.1,   12.7,  26.2,   2.5, | 64 |  , |
230 DATA   2.2,    6.9,   16.4,  22.3,   —.4, | 60.7, |
240 DATA   3.9,   11.1,   16.6,  22.7,  —3 |  , | 59.8, |
250 DATA   3.2,   13 |  ,   13.5,  21.1,  —5 |  , | 59.4, |
260 DATA    .8,   12.9,    8.9,  17.4,  —6.3, | 56.3, |
270 DATA    .3,   13.2,    6 |  ,   9.3,  —8 |  , | 52.4, |
280 DATA   0 |  ,   12.4,    4.9,   2.7,  —9 |  , | 47.6, |
290 DATA  —1.8,   11.5,    3.6,   —.9,  —8.5, | 45.2, |
300 DATA   —.3,    9.7,    4.9,  —7.1,  —8 |  , | 44 |  , |
310 DATA   —.8,    6.4,    5.5, —12.4,  —9 |  , | 41.4, |
320 DATA  —9.9,    4.9,   —1.7, —20.4, —11.5, | 38.8, |
```

```
330 DATA —17.1,   —2.4,  —15.4, —19.2, —13.8, | 34.7, |
340 DATA—111.4,  —54.7,  —24.8, —28.1, —13 |  , | 31 |  , |
350 DATA—233.6, —144.8,  —40.4, —38.4, —12.5, | 27.8, |
360 DATA—237.2, —147.3,  —44.5, —51.3, —11.1, | 26.1, |
370 DATA—292.9, —199.8, —104.5, —66.6,  —9 |  , | 25.5, |
380 X=OLR
390 DEF FNP (Y)=10  |  (Y/10)
400 IN=0
```

```
410 FOR J=1 TO 20
420 READ FE, CN, ST, EL, BK, S, BJ, CJ, SRL, D1
425 REM Calculation and composition of signal to noise and equivalent ratio
430 PN=FNP(FE+RN—50—X+5)+FNP(CN+ICNO+60)+FNP(ST+RN—50—STMR+15)     +FNP(EL+RN—50)
440 ZN=S+.4-SRL—D1—X+6.4—4.343*LOG(PN)
450 ZA=S+.8—SRL—D1—X—BK
460 IF ZA>0 THEN PE =(1+ZA/9.5) | 2—1: GOTO 470
465 PE=1E—10
470 P=FNP (—ZN)+1/PE
480 Z=—4.343*LOG(P)
490 GOSUB 660
500 G=BJ*V
510 IN=IN+G
520 NEXT J
530 PRINT ‘‘IN=’’; IN
540 LPRINT ‘‘   RN(dBA)=’’; RN; ‘‘STMR(dB)=’’; STMR; ‘‘X(dB)=’’; X; ‘‘ICN0(dB)=’’; ICN0;     ‘‘IN(dB)=’’; IN
550 GOTO 70
560 RESTORE
570 REM Speech power correction for sidetone and quality of conversation
580 IF STMR>13 THEN 590 ELSE 610
590 CS=0
600 GOTO 620
610 CS=.3*(STMR—13)
620 X=X—CS+.4085*IN—9.87
630 GOTO 390
640 END
650 REM Equivalence law and calculation of V
660 IF Z<1.74 THEN 670 ELSE 690
670 Q=Z+CJ
680 GOTO 700
690 Q=.494*Z+.88+CJ
700 V=3/(.1+10 | (—Q/10))
710 RETURN
720 REM Determination of optimum OLR
```

```
730 RNS=RN—115+.006*(RN—30) | 2—STMR—7.9

740 RNL=RN—121

750 PC=10 | (ICN0/10)

760 PRL=10 | (RNL/10)

770 PRS=10 | (RNS/10)

780 N1=4.343*LOG(PC+PRL+PRS)

790 IF N1<—80 THEN OPT=7.2:RETURN

800 OPT=7.2—(N1+80)/8

810 RETURN
```

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