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MIL-STD-3005
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DEPARTMENT OF DEFENSE TELECOMMUNICATIONS SYSTEMS STANDARD

ANALOG-TO-DIGITAL CONVERSION OF VOICE BY 2,400 BIT/SECOND MIXED EXCITATION LINEAR PREDICTION (MELP)

AMSC N/A

AREA TCSS

FOREWARD

1. This standard is approved for use by all Departments and Agencies of the Department of Defense (DoD) and is a replacement for FIPSPUB-137, Telecommunications: Analog to Digital Conversion of Voice by 2,400 Bit/Second Linear Predictive Coding.

2. This standard contains design requirements for analog-to-digital (A-D) conversion of voice by 2,400 bit/second Mixed Excitation Linear Prediction (MELP). Adherence to this standard is required to produce interoperable systems at the defined rate and to meet or exceed the minimum performance requirements.

3. Appendix A of this document contains an example of an interoperable MELP algorithm. This information is provided as guidance only.

4. Appendix B contains guidelines for verification of all new implementations of this standard. New implementations must be verified to guarantee that the standard was correctly implemented. This verification process will determine if the standard is interoperable with other MELP implementations and will verify that the performance of the implementation meets or exceeds the performance of the MELP reference coder.

5. Beneficial comments (recommendations, additions, deletions) and any pertinent data which may be of use in improving this document should be addressed to: R224, National Security Agency, 9800 Savage Road STE 6516, Ft. Meade, Maryland 20755-6516 by using the Standardization Document Improvement Proposal (DD Form 1426) appearing at the end of this document or by letter.

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APPENDIX

<u>FIGURE</u>

<u>TABLE</u>

1. SCOPE

1.1 Scope. This standard establishes interoperability and performance requirements for analog-to-digital (A-D) conversion of voice by 2,400 bit/second Mixed Excitation Linear Prediction (MELP). The requirements presented in this document must be met in order for systems to be interoperable at 2,400 bit/second. Minimum performance requirements are also provided, but may be exceeded. The performance requirements are provided in Appendix B.

2. APPLICABLE DOCUMENTS

2.1 General. Documents listed in this section are required in order for the document user to fully understand the guidance being provided by this standard.

2.2 Government documents.

2.2.1 Specifications, standards, and handbooks. The following specifications, standards, and handbooks form a part of this document to the extent herein. Unless otherwise specified, the issues of these documents are those listed in the issue of the Department of Defense Index of Specifications and Standards (DoDISS) and supplement thereto, cited in the solicitation.

STANDARDS

FEDERAL

FED-STD-1016	Telecommunications: Analog to Digital Conversion of Radio Voice by 4,800 Bit/Second Code Excited Linear Prediction (CELP)
FED-STD-1037	Glossary of Telecommunications Terms
FIPSPUB-137	Telecommunications: Analog to Digital Conversion of Voice by 2,400 Bit/Second Linear Predictive Coding

MILITARY

MIL-STD-188-113	Interoperability and Performance Standards for Analog-to-Digital Conversion Techniques

(Unless otherwise indicated, copies of the above specifications, standards, and handbooks are available from the Standardization Document Order Desk, 700 Robbins Avenue, Building 4D, Philadelphia, PA 19111-5094.)

(Copies of the Federal Information Processing Standards (FIPS) are available to Department of Defense activities from the Standardization Document Order Desk, 700 Robbins Avenue, Building 4D, Philadelphia, PA 19111-5094. Others must request copies of FIPS from the National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161-2171.)

2.2.2 Other Government documents, drawings, and publication. The following other Government documents, drawings, and publications form a part of this document to the extent specified herein. Unless otherwise specified, the issues are those cited in the solicitation.

DoDISS	Department of Defense Index of Specifications and Standards

(Copies of the DoDISS are available on a yearly subscription basis either from the Government Printing Office or the DoDSSP Subscription Services, 700 Robbins Avenue, Building 4D, Philadelphia, PA 19111-5094.)

2.3 Other publications. The following documents form a part of this standard to the extent specified herein. Unless otherwise specified, the issues of the documents which are DoD adopted should be those listed in the issue of the DoDISS specified in the solicitation. The issues of the documents which have not been adopted should be those in effect on the date of the cited DoDISS.

NORTH ATLANTIC TREATY ORGANIZATION (NATO)

STANDARDIZATION AGREEMENT (STANAG's)

STANAG 4198	Parameters and Coding Characteristics That Must be Common to Assure Interoperability of 2400 BPS Linear Predictive Encoded Digital Speech
STANAG 4209	The NATO Multi-Channel Tactical Digital Gateway -- Standards for Analogue to Digital Conversion of Speech Samples

(Application for copies should be addressed to the Naval Publications and Forms Center, 5801 Tabor Avenue, Philadelphia, PA 19120-5099.)

(Non-Government standards are generally available for reference from libraries. They are also distributed among non-Government standards bodies and using Federal agencies.)

2.4 Order of precedence. In the event of a conflict between the text of this standard and the references cited herein, the text of this standard should take precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

3. DEFINITIONS

3.1 Terms. Definitions of terms used in this standard should be as specified in the current edition of FED-STD-1037. In addition, the following definitions are applicable for the purpose of this standard.

3.1.1 Adaptive spectral enhancement. This feature enhances the formant structure of the synthetic speech by use of an adaptive spectral enhancement filter that is applied to the mixed excitation.

3.1.2 Aperiodic pulses. Aperiodic pulses are used in the excitation model of the synthesizer when the aperiodic flag is set to 1. The aperiodic flag is set to one when the jittery voiced state is encountered during the voicing decision process. This feature is used to reduce the buzzy quality of the synthetic speech signal.

3.1.3 Fourier magnitude modeling. Fourier magnitude modeling involves determining the Fourier magnitudes of the first 10 pitch harmonics of the prediction residual and vector quantizing them with 8 bits for transmission. The use of this technique improves the accuracy of the speech production model at the perceptually important lower frequencies.

3.1.4 Hamming codes. A class of linear codes used for forward error correction. These codes are used only in the unvoiced mode.

3.1.5 Jitter. Random variations introduced into the duration of a signal.

3.1.6 Linear prediction coding. A method for approximating the current speech sample by using a linear combination of past and future speech samples. This method efficiently represents a speech signal and its spectrum characteristics with a very small number of parameters when combined with an appropriate excitation signal.

3.1.7 Mixed excitation. The combination of a periodic function (such as a pulse train) and random noise for use in the excitation model. This combination is applied to sub regions of the frequency domain of the excitation signal.

3.1.8 Prediction coefficients. A set of values that are calculated using a short segment of the input speech signal and provide an estimate of the spectral properties of that signal. These values are determined by performing linear prediction analysis on the input signal. The goal of the analysis is to produce values that minimize the short term mean-squared prediction error over the input segment.

3.1.9 Pulse dispersion. Uses a fixed filter to spread the excitation energy within a pitch period.

3.1.10 Uniform quantizer. A uniform quantizer uses levels and step sizes that are distributed uniformly.

3.1.11 Weighted Euclidean distance. The euclidean distance is a distortion measure between two vectors. In this standard the euclidean distance is determined by summing the squared difference between two vectors for a select number of samples. Normally the euclidean distance is the square root of the measure described in the previous sentence.

3.2 Acronyms used in this standard. The acronyms used in this standard are defined as follows:

A-D - Analog to Digital

DoD - Department of Defense

DoDISS - Department of Defense Index of Specifications and Standards

DoDSSP - Department of Defense Single Stock Point

FEC - Forward Error Correction

LPC - Linear Prediction Coding

LSB - Least Significant Bit

LSF - Line Spectrum Frequency

MELP - Mixed Excitation Linear Predictions

MSB - Most Significant Bit

MSVQ - Multi-Stage Vector Quantizer

STANAG - Standardization Agreement

4. GENERAL REQUIREMENTS

Not applicable

5. DETAILED REQUIREMENTS

5.1 General. The Mixed Excitation Linear Prediction coder is based on the traditional Linear Prediction Coder (LPC) parametric model, but also includes five additional features. They are mixed excitation, aperiodic pulses, adaptive spectral enhancement, pulse dispersion, and Fourier magnitude modeling. A MELP frame interval is 22.5 ms ± 0.01 percent in duration and contains 180 voice samples (8,000 samples/second).

5.2 Analog specification. The recommended analog requirements for the MELP coder are for a nominal bandwidth ranging from 100 Hz to 3800 Hz. Although the MELP coder will operate with a more band limited signal, performance degradation will result. To ensure proper operation of the MELP coder, the A-D conversion process should produce peak values of (or near) -32768 and 32767. Additionally, the coder should have unity gain, which means that the output speech level should match that of the input speech.

5.3 Parameter quantization and encoding. The MELP parameters which are quantized and transmitted are the final pitch (P_3); the bandpass voicing strengths (Vbp_i, i = 1, 2, …, 5); the two gain values (G_1 and G_2); the linear prediction coefficients (a_i, i= 1, 2, …, 10); the Fourier magnitudes; and the aperiodic flag. The use of the following quantization procedures is required for interoperability among various implementations.

5.3.1 Pitch and overall voicing. The final pitch (P_3), and the low band voicing strength (Vbp_1), are quantized jointly using 7 bits, as follows. If $Vbp_1 \leq 0.6$, then the frame is unvoiced and the all-zero code is sent. Otherwise, the log of P_3 is quantized with a 99-level uniform scalar quantizer (see 5.3.7) ranging from log20 to log160. The resulting index (range 0 to 98) is then mapped to the transmitted 7-bit codeword using the encode/decode values in table I. All 28 codes with Hamming weight of 1 or 2 are reserved for error protection. This table is also used in decoding the 7-bit pitch code to determine if a frame is voiced, unvoiced, or whether a frame erasure is indicated. A frame is determined unvoiced if the pitch code is all zero or has only one bit set. If two bits are set, then a frame erasure is indicated. Otherwise, the voiced mode is used and the pitch index is determined from the received code according to table I.

TABLE I. Encode / decode table for pitch and overall voicing parameter.

Code	Index	Code	Index	Code	Index	Code	Index
0x0	UNVOICED	0x20	UNVOICED	0x40	UNVOICED	0x60	ERASURE
0x1	UNVOICED	0x21	ERASURE	0x41	ERASURE	0x61	68
0x2	UNVOICED	0x22	ERASURE	0x42	ERASURE	0x62	69
0x3	ERASURE	0x23	16	0x43	42	0x63	70
0x4	UNVOICED	0x24	ERASURE	0x44	ERASURE	0x64	71
0x5	ERASURE	0x25	17	0x45	43	0x65	72
0x6	ERASURE	0x26	18	0x46	44	0x66	73
0x7	0	0x27	19	0x47	45	0x67	74
0x8	UNVOICED	0x28	ERASURE	0x48	ERASURE	0x68	75
0x9	ERASURE	0x29	20	0x49	46	0x69	76
0xA	ERASURE	0x2A	21	0x4A	47	0x6A	77
0xB	1	0x2B	22	0x4B	48	0x6B	78
0x12	ERASURE	0x32	28	0x52	54	0x72	85
0x13	5	0x33	29	0x53	55	0x73	86
0x14	ERASURE	0x34	30	0x54	56	0x74	87
0x15	6	0x35	31	0x55	57	0x75	88
0x16	7	0x36	32	0x56	58	0x76	89
0x17	8	0x37	33	0x57	59	0x77	90
0x18	ERASURE	0x38	34	0x58	60	0x78	91
0x19	9	0x39	35	0x59	61	0x79	92
0x1A	10	0x3A	36	0x5A	62	0x7A	93
0x1B	11	0x3B	37	0x5B	63	0x7B	94
0x1C	12	0x3C	38	0x5C	64	0x7C	95
0x1D	13	0x3D	39	0x5D	65	0x7D	96
0x1E	14	0x3E	40	0x5E	66	0x7E	97
0x1F	15	0x3F	41	0x5F	67	0x7F	98

5.3.2 Bandpass voicing. When $Vbp_1 > 0.6$, the remaining bandpass voicing strengths are quantized to 1 if their value exceeds 0.6, and quantized to 0 otherwise. There is one exception. If the quantized values of Vbp_I, I = 2, 3, 4, 5 are 0001, respectively, then Vbp_5 is quantized to 0. The quantized values are transmitted using 4 bits. When $Vbp_1 \leq 0.6$, the bandpass voicing bits are replaced with FEC parity bits.

5.3.3 Gain. Two gain parameters, G_1 and G_2, are transmitted each frame. G_2 is quantized to 5 bits using a 32-level uniform quantizer ranging from 10.0 to 77.0 dB. The quantizer index is the transmitted codeword. G_1 is quantized to 3 bits using the following adaptive algorithm. This algorithm determines if the frame is a steady state frame or a transition frame. If $G_{2,}$ for the current frame, is within 5 dB of G_2 for the previous frame, and G_1 is within 3 dB of the average of G_2 values for the current and previous frames, then the frame is steady-state and a special code (all zero) is sent to indicate that the decoder should set G_1 to the mean of the G_2 values for the current and previous frames. Otherwise, the frame represents a transition and G_1 is quantized with a 7-level uniform quantizer ranging from 6 dB below the minimum of the G_2 values for the current and previous frames to 6 dB above the maximum of those G_2 values. The all-zero codeword is sent for steady state frames and a 7-bit uniform quantizer is used for transition frames. In this case, the quantizer index plus 1 is the transmitted codeword. See 5.3.7 for details on the uniform quantizer.

5.3.4 Linear prediction coefficients. The linear prediction coefficients are converted into line spectrum frequencies (LSF) and the resulting LSF vector is checked for monotonicity. If the vector is not monotonic it is adjusted accordingly. The LSF vector is also checked for minimum separation of 50 Hz and adjusted accordingly. The resulting LSF vector is then quantized by a multi-stage vector quantizer (MSVQ). The MSVQ codebook consists of four stages whose indices have 7, 6, 6, and 6 bits, respectively. The quantized LSF vector, $\hat{f}$, is the sum of the vectors selected by the search process, with one vector selected from each stage. The MSVQ search finds the codebook vector which minimizes the square of the weighted Euclidean distance, d^2, between the unquantized and quantized LSF vectors:

$$d^2(f,\hat{f}) = \sum_{i=1}^{10} w_i (f_i - \hat{f}_i)^2 \quad \text{, where } w_i = \begin{cases} P(f_i)^{0.3}, 1 \le i \le 8 \\ 0.64P(f_i)^{0.3}, i = 9 \\ 0.16P(f_i)^{0.3}, i = 10 \end{cases} \text{, } \textbf{EQUATION 1},$$

f_I is the I^{th} component of the unquantized LSF vector, and $P(f_I)$ is the inverse prediction filter power spectrum evaluated at frequency f_i. The indices of the four vectors are transmitted. The code vectors and corresponding indices are provided in tables IV-VII.

5.3.5 Fourier magnitudes. The ten Fourier magnitudes are coded with an 8-bit vector quantizer. The index of the code vector, which minimizes the weighted Euclidean distance between the input and code vectors, is transmitted. The weights are fixed and are given by:

$$w_i = [117/(25 + 75(1 + 1.4(f_i/1000)^2)^{0.69})]^2 \text{, I = 1, 2, …, 10, } \textbf{EQUATION 2},$$

where $f_I = 8000i/60$ is the frequency in Hz corresponding to the I^{th} harmonic for a default pitch period of 60 samples. The code vectors and corresponding indices are given in table VIII.

5.3.6 Aperiodic flag. The aperiodic flag is a single bit, transmitted as is. The aperiodic flag is set to 1 if $Vbp_1 < 0.5$ and set to 0 otherwise. When set, this flag tells the decoder that the pulse component of the excitation should be aperiodic, rather than periodic.

5.3.7 Uniform quantization. The pitch and gain quantization processes employ uniform quantizers which operate as follows. The stepsize for an n-level quantizer ranging from x_1 to x_2 is $s = (x_2 - x_1)/(n-1)$. The n quantizer output values are $x_1 + i \cdot s$, I = 0, 1, …, n-1. The threshold values between levels I and I+1 are $x_1 + (0.5 + i)s$, I = 0, 1, …, n-2 . The quantizer produces n indices, 0, 1, …, n-1, which correspond to an increasing value of the parameter being quantized. For example, let $x_1 = 1$, $x_2 = 7$, and n = 7. This gives s = 1, levels of 1, 2, …, 7, and thresholds of 1.5, 2.5, …, 6.5. Index 0 is assigned to input values x, for which $x \le 1.5$; index 1 is assigned to input values for which $1.5 \le x \le 2.5$; etc.

5.4 Error protection. Forward Error Correction (FEC) is implemented in the unvoiced mode only, when the Fourier magnitudes, bandpass voicing, and jitter bits need not be transmitted. FEC replaces those 13 bits with the parity bits of three Hamming (7,4) codes and one Hamming (8,4) code. These codes protect the first stage LSF index (7 bits) and both gain indices (8 bits); there is one spare information bit, set to 0.

The protected bits are placed into a column vector, u, which post-multiplies the parity generator matrix to produce the n-bit parity vector, $p = [p_0\ \ p_1\ \ \ldots\ \ p_{n-1}]^T$, where n is 3 or 4. The parity generator matrix for the Hamming (7,4) code is: $G_{7,4} = \begin{bmatrix} 1101 \\ 1011 \\ 0111 \end{bmatrix}$. The parity generator matrix for the Hamming (8,4) code is:

$$G_{8,4} = \begin{bmatrix} 1101 \\ 1011 \\ 0111 \\ 1110 \end{bmatrix}.$$

The 4 most significant bits (MSBs) of the first stage LSF index ($u = [b_6\ \ b_5\ \ b_4\ \ b_3]^T$) are protected by the (8,4) code, with the 4 parity bits written to the LSBs of the bandpass voicing index ($p_0\ \ p_1\ \ p_2\ \ p_3$). The remaining 3 bits of the first stage index and the spare bit ($u = [b_2\ \ b_1\ \ b_0\ \ 0]^T$) are protected with 3 parity bits written to the MSB's of the Fourier magnitude index ($p_0\ \ p_1\ \ p_2$). The 4 MSBs of the second gain index ($u = [b_4\ \ b_3\ \ b_2\ \ b_1]^T$) are protected with 3 parity bits written to the next 3 bits of the Fourier magnitude index ($p_0\ \ p_1\ \ p_2$). The LSB of the second gain index and the 3 bit first gain index ($u = [b_0\ \ b_2\ \ b_1\ \ b_0]^T$) are protected with 3 parity bits written to the 2 LSBs of the Fourier magnitude index ($p_0\ \ p_1$) and the aperiodic flag (p_2). The parenthesized groups of parity bits show their placement in the given index, with the right-most bit having the least significance.

5.5 Transmission format. This section provides information on the transmission rate for the coder, the number of bits allocated for each MELP frame and the transmission order for the bits in each MELP frame.

5.5.1 Transmission rate**.** The transmission rate should be 2,400 bits/s ± 0.01 percent. Since all frames contain 54 bits, the frame length is 22.5 ms ± 0.01 percent.

5.5.2 Bit allocation**.** Table II shows how the 54 bits in an MELP frame are allocated among the parameters.

TABLE II. MELP bit allocation.

Parameters	**Voiced**	**Unvoiced**
LSF's	25	25
Fourier Magnitudes	8	-
Gain (2 per frame)	8	8
Pitch, overall voicing	7	7
Bandpass Voicing	4	-
Aperiodic Flag	1	-
Error Protection	-	13
Sync Bit	1	1
Total Bits / 22.5 ms Frame	54	54

5.5.3 Bit transmission order**.** Table III shows the transmission order for the 54 bits in each MELP frame for both voiced and unvoiced frames. The sync bit alternates between 0 and 1 from frame to frame.

TABLE III. MELP bit transmission order.

Bit	Voiced	Unvoiced	Bit	Voiced	Unvoiced	Bit	Voiced	Unvoiced
1	G(2)-1	G(2)-1	19	LSF(1)-7	LSF(1)-7	37	G(1)-1	G(1)-1
2	BP-1	FEC(1)-1	20	LSF(4)-6	LSF(4)-6	38	BP-3	FEC(1)-3
3	P-1	P-1	21	P-4	P-4	39	BP-2	FEC(1)-2
4	LSF(2)-1	LSF(2)-1	22	LSF(1)-6	LSF(1)-6	40	LSF(2)-2	LSF(2)-2
5	LSF(3)-1	LSF(3)-1	23	LSF(1)-5	LSF(1)-5	41	LSF(3)-4	LSF(3)-4
6	G(2)-4	G(2)-4	24	LSF(2)-6	LSF(2)-6	42	LSF(2)-3	LSF(2)-3
7	G(2)-5	G(2)-5	25	BP-4	FEC(1)-4	43	LSF(3)-3	LSF(3)-3
8	LSF(3)-6	LSF(3)-6	26	LSF(1)-4	LSF(1)-4	44	LSF(3)-2	LSF(3)-2
9	G(2)-2	G(2)-2	27	LSF(1)-3	LSF(1)-3	45	LSF(4)-4	LSF(4)-4
10	G(2)-3	G(2)-3	28	LSF(2)-5	LSF(2)-5	46	LSF(4)-3	LSF(4)-3
11	P-5	P-5	29	LSF(4)-5	LSF(4)-5	47	AF	FEC(4)-3
12	LSF(3)-5	LSF(3)-5	30	FM-1	FEC(4)-1	48	LSF(4)-2	LSF(4)-2
13	P-6	P-6	31	LSF(1)-2	LSF(1)-2	49	FM-5	FEC(3)-3
14	P-2	P-2	32	LSF(2)-4	LSF(2)-4	50	FM-4	FEC(3)-2
15	P-3	P-3	33	FM-8	FEC(2)-3	51	FM-3	FEC(3)-1
16	LSF(4)-1	LSF(4)-1	34	FM-7	FEC(2)-2	52	FM-2	FEC(4)-2
17	P-7	P-7	35	FM-6	FEC(2)-1	53	G(1)-3	G(1)-3
18	LSF(1)-1	LSF(1)-1	36	G(1)-2	G(1)-2	54	SYNC	SYNC

NOTES:

G = Gain — BP = Bandpass Voicing

P = Pitch/Voicing — LSF = Line Spectral Frequencies

FEC = Forward Error Correction Parity Bits — FM = Fourier Magnitudes

Bit 1 = least significant bit of data set — AF = Aperiodic Flag

Highlighted Bits = 24 Most Significant MELP Bit

6. NOTES

(This section contains information of a general or explanatory nature that may be helpful, but is not mandatory.)

6.1 Intended use. This standard specifies minimum operability and performance characteristics for analog-to-digital conversion by 2,400 bit/second MELP to be used in the design and installation of new communications subsystems and equipment and in authorized upgrading of existing communications subsystems and equipment. This standard is intended to replace FIPSPUB-137.

6.2 Patent notice. The Government has government purpose license rights under the following listed patents for the benefit of manufacturers of the item for the Government or for use in equipment to be delivered to the Government.

Awarded:

Mixed Excitation Linear Prediction with Fractional Pitch, U.S. Patent Number 5,699,477

Signal Quantizer wherein Average Level Replaces Subframe, U.S. Patent Number 5,794,180

Pending:

Multi-Stage Vector Quantization with Efficient Codebook Search

Adaptive Filter and Filtering Method for Low Bit Rate Coding

6.3 Subject term (key word) listing.

2.4 kbps

2400 bps

Analog-to-digital (A-D) conversion

Encoder/decoder, MELP

Linear prediction coefficients

Low rate

MELP

MELP analyzer

MELP synthesizer

Mixed Excitation Linear Prediction (MELP)

Voice compression

Scalar quantization

Speech coding

Speech compression

Vector quantization

TABLE IV. Codebooks used by the LSF multi-stage quantizer for stage 1 (component values are in Hertz).

Index	Vector									
0x0	355.243052	492.660028	635.385928	980.347948	1837.261588	2144.996488	2413.630272	2740.714360	3093.750680	3368.605604
0x1	484.729576	640.392668	823.554944	1338.889972	1880.237972	2096.149748	2435.878020	2765.302236	3111.357628	3418.139924
0x2	436.939032	581.990372	733.911476	1083.060744	1722.101828	1952.692520	2262.632928	2665.653132	2988.244500	3298.130992
0x3	350.087600	694.610176	944.914844	1378.402864	1707.342116	2041.440136	2412.922496	2762.516244	3162.275016	3440.821584
0x4	269.325932	388.049792	556.748868	785.832892	1397.348004	1900.273176	2320.491456	2646.296664	3000.054600	3327.772772
0x5	419.087356	620.798580	850.207244	1116.317652	1781.215188	2232.204928	2499.593164	2780.066296	3175.151244	3383.999004
0x6	358.942452	489.979380	640.111288	1017.602192	1632.583372	1860.474172	2231.257076	2530.919888	2914.448960	3401.586484
0x7	342.968080	472.778640	726.418032	1259.413024	1498.007664	1891.490164	2466.558164	2714.287832	3160.189944	3419.703608
0x8	335.018920	454.914768	599.867328	961.710264	1759.619356	2105.336600	2379.626816	2706.222688	3035.591784	3319.356816
0x9	442.061924	553.856784	797.270016	1305.514352	1865.663680	2073.685500	2435.956032	2730.036752	3100.078344	3403.177804
0xa	374.716320	513.719596	672.660540	1007.318856	1678.355252	1896.143836	2248.388928	2580.640296	3008.824168	3367.792428
0xb	342.836124	602.011044	806.724744	1354.434868	1736.211376	1954.730524	2467.389528	2745.001960	3164.511124	3452.871652
0xc	257.766340	414.160796	594.258332	830.760316	1054.375184	1916.648492	2340.302436	2672.872980	3199.556716	3428.415672
0xd	292.366648	429.559640	614.610428	820.622344	1351.086544	2055.154672	2396.444508	2694.685012	3094.502340	3359.889892
0xe	298.311292	453.999408	578.280580	905.030628	1527.175416	1719.933116	2049.377252	2579.202976	2946.545800	3302.782036
0xf	336.895904	482.206380	640.568984	999.175084	1291.378696	1532.487800	2241.188304	2554.378500	2930.959524	3361.901736
0x10	258.053976	440.262800	705.940108	988.153356	1744.921772	2026.777644	2372.851292	2688.188712	3118.794236	3391.818028
0x11	471.585160	620.421768	768.090716	1082.870284.	1751.583152	1997.883516	2293.602428	2743.392004	3082.614040	3332.107592
0x12	366.246760	496.800000	672.316592	1165.549716	1447.016836	1687.916328	2294.844616	2547.156980	3219.253312	3477.200276
0x13	510.944264	676.518572	826.792700	1134.333084	1402.617564	1643.895904	2356.263864	2667.139968	3011.790276	3369.347468
0x14	255.724280	387.165300	573.545624	785.894372	1066.265316	1757.711896	2263.158644	2646.989552	3135.291852	3456.890708
0x15	378.012868	501.412328	704.314976	917.300392	1163.199952	2029.238448	2375.580324	2680.752024	3173.105664	3386.439868
0x16	363.972960	495.552612	721.780700	993.407816	1225.042276	1462.770692	1739.992988	2622.551036	3204.830068	3432.341068
0x17	464.747332	611.589924	768.577188	1014.013508	1220.578772	1596.409624	2440.187768	2705.814872	3152.642576	3428.078368

TABLE IV. Codebooks used by the LSF multi-stage quantizer for stage 1 (component values are in Hertz) - Continued.

Index	Vector									
0x18	302.335364	477.008004	604.607176	926.489164	1569.256396	1809.041736	2089.583652	2607.175324	3043.296900	3268.448912
0x19	430.245116	557.748552	772.076800	1037.343496	1262.090300	1915.895200	2312.176824	2583.310112	3099.906888	3325.009868
0x1a	349.410284	560.269912	751.892412	993.639536	1507.132780	1755.265904	2086.514692	2440.080336	2858.434696	3309.377008
0x1b	427.173948	653.323548	827.836272	1096.531816	1318.221064	1677.783892	2245.503596	2519.509312	3076.545064	3360.555120
0x1c	299.500472	447.090812	602.425292	837.466012	1040.742628	1548.003748	2279.710052	2618.330652	3105.809148	3444.257700
0x1d	328.461056	462.874748	624.498484	865.029756	1068.647964	1547.774676	2473.663648	2745.927484	3154.435812	3441.285648
0x1e	324.703880	468.558984	661.255136	962.651128	1182.703040	1462.208432	1741.390388	2450.460364	3083.241456	3370.025988
0x1f	348.534068	497.361908	665.076580	927.130960	1152.398736	1384.022008	2206.452184	2798.957392	3143.444020	3404.614276
0x20	282.540208	399.817980	600.125840	1360.887924	2103.622308	2286.514276	2588.754368	2874.624788	3225.367160	3467.056508
0x21	412.601996	656.294856	1113.328984	1647.403296	2055.375060	2312.331804	2665.064932	2918.390864	3223.101592	3484.878096
0x22	311.996136	424.640628	677.403332	1577.771676	1868.681796	2082.825792	2435.651552	2698.612244	3214.556028	3409.172052
0x23	419.770844	677.164136	1019.950432	1497.651320	1755.500792	2131.790972	2580.584380	2904.392236	3308.333156	3532.643648
0x24	259.509376	385.637168	554.562836	937.909320	1995.858280	2321.667736	2564.317268	2836.416264	3141.165228	3417.669004
0x25	259.767772	371.811012	613.365424	1265.584772	2012.314700	2213.325596	2549.977904	2808.083496	3187.912768	3452.612372
0x26	226.714780	349.493580	608.060808	1292.857408	1544.272080	1868.756264	2388.450908	2647.670600	3142.029760	3437.458604
0x27	369.138240	511.207808	754.415676	1319.551916	1697.700984	1916.897192	2447.294220	2730.763144	3177.868008	3446.004236
0x28	252.435392	381.234476	584.820988	1159.922460	1898.554296	2115.347160	2430.113732	2702.711664	3115.573444	3405.707176
0x29	319.502340	436.349812	863.773064	1682.395072	1961.092860	2203.463320	2567.750612	2839.694116	3219.440192	3422.168484
0x2a	331.862240	446.244828	660.918160	1327.774516	1694.060384	1900.696384	2279.667660	2520.622328	3213.492012	3446.511648
0x2b	400.106248	561.949040	934.342308	1358.145284	1622.604404	2013.068024	2389.652200	2769.070912	3130.311280	3413.614884
0x2c	242.657020	377.248792	522.490964	846.946680	1761.833916	2273.529980	2545.114128	2796.080976	3106.364252	3351.943212
0x2d	219.575956	360.996896	548.251128	1088.434748	1850.457128	2070.726688	2414.144860	2685.428328	3128.683452	3450.302588
0x2e	267.708968	412.078272	563.674080	1070.274400	1466.291016	1693.365224	2236.434108	2558.971412	2977.276580	3294.566092
0x2f	280.886640	416.620632	598.407264	1135.358508	1546.804680	1744.766052	2447.398760	2759.398560	3091.181864	3426.265432

TABLE IV. Codebooks used by the LSF multi-stage quantizer for stage 1 (component values are in Hertz) - Continued.

Index	Vector									
0x30	262.027288	382.135568	656.530136	1474.423620	1840.272900	2051.403696	2404.401200	2679.250592	3166.215332	3389.927400
0x31	261.244876	531.776124	972.450092	1439.603064	1863.321332	2137.972540	2506.207492	2793.512032	3204.078640	3486.612756
0x32	339.674328	453.648992	751.280204	1389.907636	1635.730336	1865.774876	2173.773284	2553.385268	3065.628208	3273.235436
0x33	341.587388	661.908516	1017.171716	1394.366888	1663.345632	1920.173796	2203.118924	2548.413908	2988.712388	3297.386536
0x34	230.146968	343.667980	551.302016	859.858328	1580.424940	1832.179784	2240.921664	2617.020472	3037.238376	3423.404416
0x35	235.039356	364.897428	689.403960	1029.605932	1665.887764	1948.938724	2346.250084	2648.456792	3069.623524	3389.224348
0x36	308.913508	449.624692	663.772816	1145.008812	1351.964772	1598.142492	1852.252004	2454.309724	2963.855000	3252.933440
0x37	257.909564	462.387712	741.203612	1052.100868	1358.228760	1622.148340	2351.586768	2675.735168	3092.801340	3413.616912
0x38	245.750260	376.103252	575.477096	922.024244	1670.456784	1903.208808	2267.835800	2608.720112	3005.315992	3260.555008
0x39	247.920760	379.176512	646.023984	1306.141840	1522.275312	2009.603136	2373.209384	2678.976628	3272.521600	3480.612912
0x3a	252.521964	397.542288	729.733388	1092.573888	1541.289920	1831.638300	2172.991212	2432.845540	2863.515608	3353.231332
0x3b	293.760896	453.119144	952.543932	1252.249068	1524.138240	1854.489388	2240.400708	2529.295340	2980.645980	3332.247948
0x3c	194.884480	303.136856	524.001072	885.984548	1473.173076	1919.383060	2355.834416	2617.938748	3072.727588	3484.182104
0x3d	221.380896	339.827248	612.828448	974.216724	1296.283708	1802.879000	2241.073592	2652.630088	3095.005464	3428.844228
0x3e	346.441260	477.961284	659.909792	1048.696260	1321.778992	1560.564952	1860.835916	2137.948484	3028.669084	3357.727232
0x3f	306.865700	452.086676	606.287508	958.052088	1271.102660	1499.649856	2168.586976	2510.451536	2942.205140	3376.739692
0x40	367.577380	588.407212	947.277508	1401.718148	1710.042324	2095.772072	2530.043540	2877.200112	3307.829148	3539.939676
0x41	528.676400	819.913676	1280.496720	1637.511820	2066.765212	2453.835716	2824.688768	3094.627148	3371.254420	3558.843104
0x42	545.224416	669.303732	909.509712	1447.146740	1725.206608	1977.595112	2404.918460	2678.227616	3059.974176	3374.444120
0x43	502.175120	755.642512	1138.330556	1488.741484	1860.131964	2268.931212	2653.297860	2991.633600	3339.490956	3557.739556
0x44	298.315792	427.893476	578.377140	1139.800860	1526.635152	1746.979136	2250.458972	2556.079216	2919.105144	3394.443520
0x45	265.345712	679.203144	917.211964	1262.558816	1777.907428	2105.336432	2492.856668	2845.667064	3222.134752	3475.157160
0x46	459.013600	591.152844	773.066500	1211.262108	1477.162912	1731.845324	2117.279752	2387.897856	3042.563168	3318.468632
0x47	465.500052	607.671140	777.227012	1332.425448	1605.648308	1856.328328	2352.959464	2590.842552	3102.572804	3381.365096
0x48	362.053116	490.137184	745.960236	1269.985928	1492.284812	2059.254896	2441.930800	2750.527340	3227.946188	3436.200692

TABLE IV. Codebooks used by the LSF multi-stage quantizer for stage 1 (component values are in Hertz) - Continued.

Index	Vector									
0x49	421.179164	630.471988	1028.686908	1430.931296	1863.460944	2272.510540	2652.559160	2934.399884	3308.053440	3523.167936
0x4a	429.689288	559.663168	757.935192	1288.938980	1578.246504	1827.549852	2323.808836	2595.758796	3042.781576	3317.780068
0x4b	483.431132	665.740556	914.168828	1187.178920	1730.056668	2160.592152	2538.107676	2833.483468	3214.963528	3447.815624
0x4c	251.069756	400.132356	683.248580	1007.969788	1282.548200	1622.331828	2215.831796	2558.840008	3112.782068	3417.389900
0x4d	320.443576	444.544064	670.428836	1086.773516	1537.545492	1759.446916	2524.721292	2806.092276	3163.121480	3453.870028
0x4e	425.424868	566.142816	749.368748	1166.345352	1466.362360	1699.247384	2074.299292	2340.129404	2887.294576	3185.769968
0x4f	322.007664	468.376272	648.322576	1159.563560	1396.322072	1703.074704	2296.020136	2519.346720	3200.100636	3455.035180
0x50	320.644656	596.099288	959.540408	1218.782764	1581.902180	1962.503884	2385.921440	2708.652388	3210.663204	3479.108204
0x51	579.432324	803.501624	1126.062900	1427.862412	1802.430756	2082.734724	2515.367492	2857.989008	3233.182996	3504.253028
0x52	551.063564	710.286864	942.023808	1248.062556	1525.983900	1786.259580	2161.901320	2562.831384	3071.864428	3363.444284
0x53	609.760980	780.872944	980.693916	1270.962256	1550.882860	1844.290896	2341.687584	2627.830008	3095.457540	3424.026632
0x54	368.966568	542.830728	697.958024	962.227744	1185.370252	1618.496044	2046.085300	2329.287928	2995.799936	3309.116368
0x55	404.026008	558.097656	811.595992	1010.628240	1461.065508	2015.035896	2351.943240	2684.544988	3120.826572	3372.178544
0x56	467.432068	604.514196	811.435040	1070.217980	1340.694896	1626.960300	1978.396652	2451.284304	2871.931440	3178.879984
0x57	483.238296	618.742476	778.447980	1096.796044	1376.987232	1594.994712	2291.458884	2625.138056	2974.698368	3369.527960
0x58	379.418368	521.726544	730.197388	1034.923576	1254.589772	1880.551824	2225.600464	2536.139916	3027.365712	3270.175404
0x59	484.397464	617.122684	839.871000	1142.679472	1409.236340	2002.964060	2395.110708	2680.156916	3127.463592	3368.707032
0x5a	379.080976	610.318280	777.690424	1032.213916	1526.638640	1755.544788	2096.849712	2563.884348	2924.848488	3252.445700
0x5b	519.918808	686.437444	889.952740	1122.475300	1354.885456	1721.585208	2279.554208	2577.343264	3148.668212	3417.217104
0x5c	327.841264	480.902284	620.889844	893.219008	1114.708076	1389.494440	2100.358500	2641.157268	3058.513220	3378.730548
0x5d	355.124124	483.658108	677.123732	879.520776	1104.300568	1866.184292	2279.529380	2581.821656	3144.676444	3369.651800
0x5e	394.104452	587.768788	783.373896	1038.643028	1318.632312	1564.741340	2021.770288	2385.037484	2817.015404	3289.634680
0x5f	419.169056	568.314168	734.757796	982.644060	1183.660644	1521.688088	2411.250204	2684.267700	3102.943040	3407.177224
0x60	217.051472	442.467788	1167.844336	1599.059960	1943.541700	2342.287000	2754.109460	3023.786416	3368.479160	3560.444724
0x61	548.527208	936.006868	1550.171484	1861.420968	2197.263736	2455.181020	2730.234412	2965.074536	3243.046748	3471.871480

TABLE IV. Codebooks used by the LSF multi-stage quantizer for stage 1 (component values are in Hertz) - Continued.

Index	Vector									
0x62	429.353204	649.857460	1241.313404	1625.726460	1852.896036	2164.172340	2490.051440	2778.301472	3199.920908	3454.966864
0x63	530.200920	767.252124	1229.137072	1718.003588	2078.513660	2358.501028	2693.879268	2963.116860	3269.410220	3513.980576
0x64	180.250056	286.314476	782.009868	1256.403520	1607.783616	1964.381668	2428.505580	2763.402500	3181.404500	3497.090480
0x65	363.046928	495.176544	932.244352	1723.729152	2069.873516	2266.036024	2598.054636	2863.095040	3218.926356	3530.567056
0x66	275.456260	401.919616	743.453280	1360.345704	1599.375664	1867.905052	2173.127540	2584.451656	3032.595160	3309.266888
0x67	497.729776	703.060684	1036.341080	1397.418484	1838.024488	2064.417060	2475.461776	2841.367628	3176.211216	3468.295196
0x68	218.701004	364.654668	847.953432	1455.778028	1822.566468	2271.184816	2688.881072	3009.378188	3344.588860	3544.795392
0x69	409.265696	722.538580	1459.908136	1792.828940	2125.621812	2424.411352	2670.935304	2920.454980	3237.822100	3467.081936
0x6a	458.000836	574.728436	974.289496	1430.359792	1689.177736	1976.396512	2406.885924	2657.533792	3115.931004	3439.716700
0x6b	522.480632	818.682484	1332.380228	1637.908688	1904.114776	2177.842412	2487.380184	2815.092956	3239.457384	3495.550436
0x6c	215.477808	328.983084	581.950052	997.003380	1496.216816	1965.586408	2358.623932	2637.005088	3023.330960	3434.554392
0x6d	211.424108	336.110144	846.609096	1295.560356	1629.676036	2078.982732	2435.617148	2785.006628	3211.635028	3492.684188
0x6e	301.433204	429.696220	623.869464	1219.478592	1673.674336	1872.317560	2228.603416	2498.196592	3095.581436	3326.314400
0x6f	227.796312	619.235776	903.737200	1186.101972	1486.952480	1881.668384	2408.921256	2705.309088	3149.776640	3445.450360
0x70	246.964648	410.663624	963.556232	1336.930556	1805.419368	2107.567904	2494.256680	2767.940768	3170.005316	3459.535500
0x71	311.054428	696.503640	1198.813572	1667.222600	2009.052656	2402.897624	2794.768432	3103.142944	3356.889572	3553.501980
0x72	376.233832	487.344044	957.121240	1293.941648	1542.461412	1934.271352	2279.849188	2603.799128	3020.524136	3276.772280
0x73	420.577340	782.720780	1157.816496	1409.439164	1730.193544	2036.551884	2542.586672	2940.837648	3295.060216	3536.318668
0x74	227.450880	354.217032	645.854024	1103.949568	1457.017632	1735.123748	2145.927528	2434.094168	2993.342528	3398.840732
0x75	298.009992	505.689304	804.054936	1230.271608	1782.344852	2092.537116	2531.424824	2811.813824	3208.324332	3479.810704
0x76	361.837248	481.881860	754.778976	1157.999988	1373.736592	1603.401296	1872.798780	2597.556168	3080.013080	3322.141852
0x77	363.145448	654.603360	851.016964	1201.750484	1524.731340	1765.555460	2194.217812	2663.022320	3094.972416	3372.444548
0x78	244.837812	378.566316	819.184860	1063.961972	1389.825920	1926.440476	2268.995564	2555.088408	3159.662448	3442.437796
0x79	289.878276	678.873488	1094.283708	1378.083076	1669.550396	2126.537152	2546.927840	2938.947780	3349.758448	3564.281964
0x7a	291.135372	603.970104	806.647404	1146.202408	1492.922632	1738.308380	2185.345584	2532.566400	3038.664848	3362.383560

TABLE IV. Codebooks used by the LSF multi-stage quantizer for stage 1 (component values are in Hertz) - Continued.

Index	Vector									
0x7b	477.451948	711.119268	1120.567768	1400.126952	1652.650504	1928.385468	2281.368392	2627.063532	3117.426876	3435.299932
0x7c	197.859932	317.615912	561.566488	1004.156772	1272.079512	1786.734928	2269.843440	2576.009008	3054.133780	3435.857468
0x7d	209.857268	338.088960	742.900840	1010.365752	1329.130948	1933.476212	2274.220164	2550.770696	2992.557772	3438.759304
0x7e	371.540116	517.541568	699.734220	1056.769240	1360.004676	1581.063852	1896.072308	2138.187064	2982.447132	3386.475496
0x7f	421.325684	565.415952	733.196828	987.054432	1189.015404	1594.283500	2041.152924	2300.535092	3176.614820	3416.630796

TABLE V. Codebooks used by the LSF multi-stage quantizer for stage 2 (component values are in Hertz).

Index	Vector									
0x0	-1.083480	-11.578352	2.306316	-13.996316	-69.456300	37.766424	-72.555080	-159.215592	-339.818812	-152.118616
0x1	-49.649148	-46.254812	-78.096196	-42.879304	87.142444	6.807124	-84.402392	-169.554840	114.687420	84.983800
0x2	-64.871376	-74.238856	-98.423948	73.693940	8.272440	-0.445588	-69.719076	-97.613228	-113.804960	-72.737376
0x3	-76.670260	-104.000124	162.718804	146.267556	35.949460	-54.029504	-165.439464	-56.673624	-30.629936	-20.631364
0x4	79.209324	69.866840	42.538208	-8.700224	-41.525928	-87.881980	-172.058432	-257.161664	-205.789544	-58.729048
0x5	46.523288	32.708904	16.372320	87.959672	17.893436	-31.334540	-158.771560	-210.683128	50.801572	-1.070176
0x6	-24.884988	89.877856	60.112892	-46.721488	-88.565924	-123.916356	-98.926960	-105.548976	-49.521476	-27.839204
0x7	12.216416	-10.885964	50.445364	113.287312	44.675968	7.914896	-81.805228	-145.891432	-269.429460	-201.234052
0x8	-18.702440	-28.966588	-107.616672	-54.971216	189.132464	132.336076	-7.024808	-69.746976	-94.375328	-6.820516
0x9	-56.894540	-72.024184	-52.360740	193.625260	129.735560	62.003412	-71.477448	-142.162752	64.098872	11.162704
0xa	-60.650768	-78.194956	-63.935496	64.655352	-25.341792	84.625644	73.669276	12.005084	149.501796	80.509048
0xb	-15.112784	-31.196064	3.849784	159.434312	93.375988	58.684128	-41.109156	87.189492	131.801980	56.989420
0xc	19.254800	29.158032	-18.931012	-97.893236	63.340576	-10.453596	-104.093976	-176.150796	-211.962572	-17.986996
0xd	43.597972	19.186704	57.392544	116.543328	78.867444	26.069228	-78.842272	-162.151528	142.039780	80.101388
0xe	-80.512424	6.911116	10.447620	-20.670668	122.874212	64.969424	-20.095012	-41.500620	40.870524	27.243612
0xf	15.133536	-11.533644	91.378952	186.566144	151.176812	106.171932	-10.561384	-69.816204	-158.913692	-147.982316
0x10	-22.857064	-45.429420	43.667084	21.242924	-51.172664	132.138704	25.815592	40.259908	-43.876200	-80.833196
0x11	-34.458148	-37.767448	-50.349484	-21.896640	91.649508	17.432224	65.073496	11.976292	-123.733292	-107.504528
0x12	-22.611732	-44.342752	65.095116	32.444480	-57.425188	-5.691424	138.519252	62.980136	71.781844	39.682944
0x13	-54.683340	-52.559476	144.402736	36.354708	-66.256948	-121.447840	-47.001024	19.677400	55.941392	46.382952
0x14	76.995752	60.130164	57.113272	18.707744	-53.600588	62.799420	-40.517780	-114.388064	-26.126324	-73.326320
0x15	25.816108	31.076704	124.868068	63.559872	51.002984	-27.654288	-97.466628	-21.956264	-41.809916	-45.055148
0x16	-45.228580	102.897240	83.947112	74.901616	49.974708	8.687204	48.971348	6.900972	-8.644580	-8.383932
0x17	61.045120	182.798948	159.671368	59.777160	29.855824	-31.491100	-95.978064	-78.175532	-39.050008	-13.743948

TABLE V. Codebooks used by the LSF multi-stage quantizer for stage 2 (component values are in Hertz) - Continued.

Index	Vector									
0x18	49.646432	28.451656	67.128192	0.886752	-49.083656	188.228948	106.267192	13.855044	-160.204028	-171.642896
0x19	-10.121400	-10.494132	-51.702072	-102.624176	212.475096	189.695604	82.285124	56.342688	-4.878576	-11.235844
0x1a	36.358408	21.779392	42.357136	2.492964	-42.223212	230.770844	160.695752	154.000972	136.475152	53.130348
0x1b	-29.676572	-39.223244	-35.661060	94.983248	59.318312	2.700204	207.235004	137.851652	158.257256	108.921592
0x1c	122.140104	120.913744	108.201320	67.247396	59.132704	40.026908	43.540560	8.987920	-51.137704	-38.635328
0x1d	72.657632	68.934704	16.956396	25.957480	190.086812	142.948388	53.217716	2.736948	-59.085276	-22.405936
0x1e	25.878136	32.075092	-18.051520	129.615436	41.005184	141.842100	80.837536	-5.850756	113.953980	43.969864
0x1f	56.950488	37.665072	132.514492	135.379112	75.671416	138.633300	118.390580	101.879640	101.928352	42.930520
0x20	22.106900	21.059164	-34.232504	-93.793160	-155.416992	-194.590552	20.038956	-23.649856	-114.881156	11.324568
0x21	-26.033500	-35.961000	-61.732092	-162.427040	-26.287444	-98.269260	-141.894620	95.126388	-1.505500	-7.727060
0x22	-31.289284	-49.998772	-67.781776	-161.027220	-175.279260	-225.390404	-61.840204	0.995364	16.801380	48.424344
0x23	-86.553744	-108.489556	-17.654176	-72.132484	-7.564812	8.047932	-86.936256	27.160092	12.540832	22.373696
0x24	17.779300	15.339312	-36.725424	-8.881500	-102.852904	-144.867340	-94.816980	-196.287232	76.219908	45.250160
0x25	-19.692492	-30.220916	-29.782548	17.903896	-49.210684	-116.668528	-256.575612	-267.358620	139.673908	78.124496
0x26	-19.207108	4.375076	21.642788	-48.371256	-77.052304	-161.254660	-158.684868	250.771480	151.906788	53.175120
0x27	-16.784044	-37.622168	5.782012	-19.570792	-88.589344	-117.076008	-236.655112	-78.102088	-107.415260	-79.445552
0x28	-33.759476	-44.175904	-74.702140	-135.044380	-188.927648	7.016552	82.302568	25.474344	76.734852	27.800992
0x29	-86.590864	-120.632148	-148.796704	-150.115860	-18.258660	-84.054596	2.635176	37.246548	34.580064	56.689732
0x2a	-70.539400	-83.361280	-55.232632	-27.094692	-100.538976	-172.089768	53.281532	-13.033652	9.663312	46.571280
0x2b	-51.370904	-79.509096	-141.551088	1.691600	57.508000	-53.104592	20.961464	69.160500	48.868372	37.564824
0x2c	-26.397896	-22.278824	-58.177544	-99.990728	-151.064636	-22.789692	-120.173196	-151.092736	-107.237000	-84.906792
0x2d	20.239624	4.006208	-28.664352	-11.823076	-26.946228	-66.325064	-59.575592	-61.081748	-37.028000	-19.087332
0x2e	-32.526320	6.534672	-84.214076	-41.573904	-42.894712	-81.510608	52.840208	-43.398352	72.024408	68.427864
0x2f	5.449508	-14.963136	-41.741028	103.234668	14.390108	-64.423760	100.949988	29.811640	-101.778792	-32.993828

TABLE V. Codebooks used by the LSF multi-stage quantizer for stage 2 (component values are in Hertz) - Continued.

Index	Vector									
0x30	32.295632	18.407260	-5.894076	-74.483888	-152.963476	-204.044336	205.952264	219.522920	81.562784	61.202332
0x31	18.857140	38.485396	-0.989396	-55.047384	-48.776448	-130.013268	107.102480	146.292968	-43.136920	12.888356
0x32	-0.859316	-10.029480	-5.970772	-37.158360	-112.881804	25.395820	308.705512	231.753228	148.199332	77.118376
0x33	-74.718268	-7.140804	45.716792	5.980372	66.215188	4.203068	147.785360	193.993040	80.089172	48.570476
0x34	66.596548	54.383604	27.843772	2.162152	-78.289776	-136.087776	83.808688	-2.700500	-13.633996	6.292336
0x35	44.048796	18.914496	31.356536	6.002560	-53.040524	-33.569576	-141.531972	117.338852	58.633508	3.317584
0x36	76.666832	98.370332	72.228980	-23.754456	-51.177288	-139.149128	-102.191076	116.960600	-15.327760	-19.772720
0x37	-24.797384	74.266648	59.426828	-45.806184	45.466244	-18.249196	-27.625136	91.983212	-22.390700	-14.842720
0x38	3.038084	-17.986644	-39.902620	-148.611816	-165.180916	177.990356	106.139356	34.196816	-54.350296	-73.378024
0x39	-44.622868	-69.180132	-94.306064	-155.434984	79.510788	55.263412	99.390112	160.956712	93.086912	48.449336
0x3a	8.528100	-16.482720	-20.536552	-119.745020	-107.365876	343.542148	310.162272	223.345188	122.204876	31.527824
0x3b	-74.730600	-98.813932	-83.739676	156.816160	172.775428	133.228172	117.447612	109.584436	74.203304	39.213180
0x3c	101.110828	100.613404	64.945400	25.583900	-51.148460	26.378476	-3.647860	-4.167064	141.475064	72.420388
0x3d	27.756364	14.300488	-39.955176	-107.269680	92.431928	47.216472	-69.001244	85.735160	-57.945236	-63.784492
0x3e	71.977736	63.828088	-0.871592	-13.855768	26.229036	-35.582384	133.902408	73.158532	103.646080	78.834900
0x3f	21.330804	14.734456	35.994576	35.047512	175.516392	109.080608	55.660600	48.472556	81.337388	54.264844

TABLE VI. Codebooks used by the LSF multi-stage quantizer for stage 3 (component values are in Hertz).

Index	Vectors									
0x0	32.980820	12.950916	-77.521608	3.457884	21.115608	-18.522344	8.594232	-32.455536	79.444108	57.096016
0x1	20.015652	21.871904	-34.912312	79.791640	42.794480	37.292348	53.149448	-12.294248	-122.971792	-61.566184
0x2	14.547848	-5.648276	8.130888	-50.548700	-72.212136	99.232328	-8.558232	-91.476160	75.606244	29.898352
0x3	46.408076	31.719192	13.758460	3.196728	-60.667004	96.666596	30.653072	-35.450592	-54.536580	-83.284228
0x4	-6.354040	-25.223476	-47.876560	-60.932144	82.686748	36.111092	64.983628	82.850232	72.591960	48.383168
0x5	-29.084848	25.116264	-32.724520	36.106892	14.532280	-62.664768	98.917540	40.993596	64.825552	65.144396
0x6	-0.834372	-21.045296	5.294624	-4.912748	-69.596788	125.862880	43.944528	64.578124	72.109888	20.414812
0x7	25.715576	39.154404	-28.547164	-23.826392	-71.987108	80.416488	61.762952	28.096916	80.217544	25.150576
0x8	-21.216668	0.919060	-54.469596	0.970748	47.454988	79.039928	41.946800	23.543096	-61.798552	-52.983464
0x9	-19.268628	-34.590936	16.035816	29.048544	85.936380	66.712128	53.866020	-9.536316	46.423792	40.015764
0xa	-14.294308	-28.466636	24.792780	-69.392596	1.677280	112.654604	35.839992	-4.488360	-87.320780	-64.399692
0xb	32.723716	17.351404	63.382408	13.164984	7.863884	32.270756	32.808984	-40.712860	-159.488912	-86.625816
0xc	27.919388	2.081884	-40.560004	-85.742272	45.749008	26.365512	-37.336432	91.871792	-15.125316	-27.295192
0xd	-103.942848	30.868692	22.905368	3.245652	-10.864848	25.740888	32.632356	14.937776	62.672404	36.229100
0xe	-13.644212	-33.497264	7.802936	-32.739608	-68.895376	-14.978252	-13.743132	-67.160192	-154.790440	-35.284996
0xf	-61.220672	-60.013976	103.693816	39.152964	37.872412	55.039632	39.596404	-12.290740	-19.392204	-4.557552
0x10	32.505808	15.583912	1.784144	53.673772	73.051196	41.469356	-64.896556	-7.048480	18.025100	-10.024028
0x11	11.483176	5.944724	17.110496	14.790684	6.431540	-20.200572	-56.308788	-134.147400	-214.746576	-59.407628
0x12	43.566172	18.989652	55.144036	-3.929840	-37.379720	61.812216	-49.526292	114.098232	69.485776	21.475288
0x13	37.469540	28.346816	15.723080	-28.085444	-6.623116	-19.773952	-66.349236	-31.002968	-146.990804	-120.377684
0x14	1.120132	-4.159908	-14.437336	-127.887976	77.027304	45.315748	29.269936	-15.638068	8.620996	14.473280
0x15	44.768968	30.467760	-6.543172	-95.704460	26.850796	-15.394560	-25.588856	-47.367504	-2.881176	39.420112
0x16	-10.057328	2.399412	1.061956	-65.695228	20.687476	-14.959904	-117.018512	92.386240	85.463796	24.175728
0x17	49.644532	65.386288	9.684648	18.181104	-14.139504	-5.888800	-38.585284	-27.183620	58.865948	16.431968

TABLE VI. Codebooks used by the LSF multi-stage quantizer for stage 3 (component values are in Hertz) - Continued.

Index	Vectors									
0x18	-16.380640	-34.278140	0.022544	56.067304	46.892096	30.245204	-28.026068	93.529428	-56.789800	-54.481380
0x19	-4.060036	-29.094112	-52.545100	79.031108	69.252092	14.267812	9.463936	-65.250772	20.751184	37.524948
0x1a	4.583084	-24.872664	107.840788	43.419736	-1.250280	-4.026280	-63.961776	21.494468	-36.229604	-32.554624
0x1b	2.165696	-29.151980	54.527780	94.168364	66.493356	36.958832	1.594416	-62.430724	-87.198932	-28.883704
0x1c	-11.601520	-21.077228	-18.656652	-63.311928	81.936576	29.605552	-50.989424	-103.844388	-74.116364	-25.022808
0x1d	-20.789816	23.424964	27.131436	-24.919604	70.569748	26.853608	-31.525276	-87.182472	84.545612	70.302900
0x1e	-49.936228	-3.446516	40.200364	-18.647372	21.569628	-58.944872	-17.371572	-22.311184	-101.189676	-49.805164
0x1f	-57.177432	62.058144	36.515704	55.561188	6.520588	6.297884	-13.632288	-52.826640	-55.443100	-54.692008
0x20	6.249736	5.520744	-30.373784	-42.147600	20.147836	-39.570052	54.020328	-16.561300	-203.250932	20.377448
0x21	-35.205168	5.085324	-51.336656	22.956972	-28.242884	-23.552672	32.053652	-17.893740	-122.073052	-160.749456
0x22	24.945192	13.164164	11.748732	-76.478132	-4.066148	-22.276580	79.811928	50.662004	-81.866692	-54.017108
0x23	40.838864	33.272060	3.666024	12.769580	-45.868448	-68.480588	92.137976	47.209512	-35.710004	-18.718076
0x24	-13.862480	-29.688380	-16.062832	-30.689744	-21.411228	-15.875376	131.557968	101.900708	23.649376	27.497916
0x25	-20.078528	-17.911912	-24.694752	-20.037984	-59.345372	-122.612400	71.623648	21.364328	43.982568	41.915580
0x26	13.955236	-13.670672	-0.176880	-47.697124	-55.913972	-56.124192	62.862572	-2.427248	142.154476	104.877084
0x27	40.271076	23.012344	27.510152	-41.497056	-55.530680	-58.212060	8.071216	-61.794624	51.734348	33.354252
0x28	8.497868	-2.606700	-30.219332	78.619552	30.672148	61.511100	30.235552	110.460236	100.718520	53.177352
0x29	-20.167520	-14.445504	-9.336176	127.582768	-4.294328	-27.401844	61.786412	21.701036	22.223068	15.230212
0x2a	-1.647608	54.368956	37.237244	-17.980500	42.437252	27.778416	60.653436	59.946944	14.306756	-5.660356
0x2b	13.352932	-14.668488	56.844876	39.456184	25.357476	11.232768	96.450116	63.098048	-28.823600	-11.658464
0x2c	16.214176	14.498636	-9.273052	-9.045960	-27.283232	-48.963732	39.335716	193.888504	87.750712	40.073856
0x2d	-47.007404	-53.423716	9.553404	0.589152	-50.564088	-1.666356	-7.432612	56.997036	53.725740	20.053884
0x2e	-36.631948	37.397136	27.393352	-30.540160	-93.368500	-20.053984	-17.314104	-0.911252	14.602000	0.825528
0x2f	-1.395788	-13.464588	93.489772	-1.615688	-30.138632	-48.064896	15.280056	66.923052	69.265380	43.586932

TABLE VI. Codebooks used by the LSF multi-stage quantizer for stage 3 (component values are in Hertz) - Continued.

Index	Vectors									
0x30	10.569172	24.809296	-60.304192	-48.704888	-38.084248	-30.716660	-41.121760	-46.544012	-33.652504	-45.618716
0x31	14.329408	2.787968	1.889624	17.819504	-36.893736	-131.985160	-0.567740	-55.884160	-72.492488	-31.240228
0x32	27.387340	7.644616	27.150636	-5.574300	-36.398996	-76.648084	-129.163304	86.750668	45.036408	6.367308
0x33	51.258220	25.407856	15.030632	72.681664	-0.275320	-33.546500	-44.555092	67.260580	-40.684228	-43.996440
0x34	-25.149456	-55.373592	-20.508880	-59.104064	39.694332	-29.855136	23.338884	-29.142064	-15.073252	16.158980
0x35	-24.028792	-33.787436	7.601280	-28.737668	-9.413580	-62.113404	-56.180560	-121.529172	83.351164	60.314356
0x36	27.417444	7.533384	0.415240	-4.640872	-21.214400	-41.096728	-104.321976	-151.643732	171.809252	110.383744
0x37	34.088864	14.909740	58.394348	39.166456	2.694692	-32.094636	-33.619456	-101.999952	32.469464	32.881976
0x38	-13.082648	-30.073608	-85.362912	6.847348	-46.908688	36.769352	43.168012	8.622884	-8.777696	-8.067804
0x39	-41.948776	1.387452	-52.071212	73.038768	4.876640	-17.894024	-51.727328	-70.581328	17.584816	-10.379668
0x3a	-12.247768	-11.237092	-44.331148	30.028040	-39.230748	-2.865544	-119.814076	72.574860	-49.888108	-64.795236
0x3b	8.651028	-16.327560	0.858176	49.272304	-33.946904	45.591748	-8.960968	-67.881588	-94.941176	-110.256420
0x3c	-12.528140	-28.219792	-66.117904	19.523384	2.767992	-68.743624	-86.900348	91.572472	64.267052	42.045840
0x3d	-18.846356	-40.824100	-12.869724	6.287764	-18.501512	23.048256	-60.021784	-20.368256	222.374712	136.273740
0x3e	-65.678876	21.048360	10.027512	27.274816	12.681548	-38.586556	-102.199520	98.262288	55.721236	13.438876
0x3f	30.881868	20.481092	5.767264	58.983840	24.991944	11.221364	42.022696	-42.025784	160.539288	108.165892

TABLE VII. Codebooks used by the LSF multi-stage quantizer for stage 4 (component values are in Hertz).

Index	Vectors									
0x0	13.864392	-19.737336	20.320452	-1.373732	-24.025380	55.403468	-33.427036	-7.164116	-76.739792	-66.680096
0x1	-22.288548	-34.188684	20.704048	-14.170992	28.366312	-25.985648	-43.561588	15.943264	46.563540	34.635664
0x2	-9.949592	14.031280	2.022688	61.570748	11.537028	-20.475192	-56.247088	12.789900	-24.688080	-20.578288
0x3	-64.483988	-2.641932	9.354576	-1.695224	-11.159228	1.977040	3.499672	18.992872	-28.880704	-17.282880
0x4	1.859316	-18.637868	39.190940	19.354980	44.978516	5.672544	-3.360900	30.381176	-52.519360	-41.922064
0x5	22.329840	-8.827276	35.918016	-26.647964	26.134024	-41.064820	4.758780	-49.390996	7.984100	30.442724
0x6	17.873364	-3.982856	44.497744	39.808760	-3.764812	-8.364812	-35.478012	-11.361596	80.956140	54.743676
0x7	7.958560	-32.041208	17.138880	37.115176	17.563628	-11.659032	33.656416	-18.415836	59.808248	36.363976
0x8	-12.145288	-24.479824	56.629472	-11.682896	-31.763652	3.683420	-20.414980	-31.909604	9.772540	-1.279444
0x9	-14.054776	-35.296828	-19.199396	17.575908	-28.405600	-4.153392	7.303092	-29.658076	-44.023168	-79.546640
0xa	11.007008	19.022892	28.676476	8.685068	41.181528	9.850048	-35.909068	-57.330104	7.240120	18.847528
0xb	-11.754804	-0.200860	-0.397848	16.824616	41.821960	15.431596	-17.873084	-46.166628	-113.237564	3.930596
0xc	4.417632	-13.858636	25.993272	3.621776	-13.282620	-54.866568	-25.740860	-8.207356	-102.337520	-90.469400
0xd	30.472892	2.402004	-8.414600	-14.939776	20.846288	-42.379776	44.159640	-1.039776	-86.199308	-29.886620
0xe	20.803664	-5.884716	-10.076072	34.678792	-1.836392	-5.648408	-57.621056	-64.743808	-35.249396	-36.447272
0xf	5.240548	-7.730720	-42.546312	25.064936	15.738880	6.281712	21.895068	5.559424	-104.670464	-52.286052
0x10	24.895620	3.387108	14.067512	-35.964624	34.713716	56.939140	17.696072	-3.026896	-64.985692	-46.711140
0x11	-20.307876	32.490736	-8.269384	-37.426408	15.369516	5.518868	-40.295176	49.790088	-30.418412	-28.439284
0x12	3.301884	23.180704	-24.454116	-5.660896	-46.692200	72.857908	3.808256	-13.518736	-27.566972	-39.098900
0x13	-36.148208	33.906036	-10.643360	27.813232	7.439476	23.088892	41.102328	-5.758800	-57.094056	-38.619512
0x14	41.485516	33.976276	16.557244	11.715616	1.168420	11.215132	2.419500	-2.189148	-20.660864	-20.782992
0x15	-34.868980	44.335072	18.371036	-9.576508	6.842808	-28.376484	-20.193584	-36.100756	-56.015728	-32.668848
0x16	22.181968	-4.747624	-6.587840	19.194412	13.324592	50.283068	34.604528	-63.345460	-24.597824	18.117740
0x17	-23.391532	11.590768	37.601468	12.769832	-9.503604	-11.279292	54.145876	-50.561068	11.992376	13.849812

TABLE VII. Codebooks used by the LSF multi-stage quantizer for stage 4 (component values are in Hertz) - Continued.

Index	Vectors								
0x18	-7.408196	-30.925108	18.743584	-54.589100	40.004624	22.577360	8.870712	-11.437640	1.800908	16.894572
0x19	2.106444	-17.324588	-22.842364	-28.871344	-21.276340	-13.394672	23.784676	70.579396	-37.411672	-52.086276
0x1a	15.241316	17.603468	-41.962316	-4.684472	53.083624	16.845052	-13.084284	-12.831660	-7.038208	-2.189224
0x1b	-5.009304	-10.205264	-23.680948	-23.020348	55.499976	26.375932	64.954384	7.736592	-5.772604	-18.452616
0x1c	17.559028	9.416808	39.605736	23.848632	1.871332	-54.038420	27.998276	35.575168	-29.006648	-1.178764
0x1d	-6.962476	4.105532	19.244696	-23.883640	-39.505700	19.590216	53.142492	8.583808	-84.255052	-13.993440
0x1e	29.861688	7.994612	-19.893828	45.102624	8.184900	-39.195660	30.159276	-34.246888	17.732108	23.665304
0x1f	14.491724	-5.943524	-5.773136	28.083748	-36.821584	-25.838832	80.000780	12.158860	-10.060840	-7.431432
0x20	-5.468828	-26.673576	-13.033748	15.823448	2.773560	29.638816	-77.755704	29.586208	3.212960	-27.223712
0x21	4.192508	-0.595220	-9.597436	-29.569652	-8.967564	-15.488152	-87.442240	33.505968	81.622340	43.421084
0x22	6.918280	5.475584	-34.010376	55.845532	3.372104	41.049620	-16.152440	1.566632	52.853932	16.039552
0x23	-38.947288	18.104492	-36.755712	-14.831836	14.532324	-0.120888	0.709208	-29.737616	63.593660	43.486380
0x24	16.827216	-8.372392	-4.047592	14.480476	48.383496	8.909460	-23.019528	74.803304	51.072416	26.536640
0x25	16.908200	3.113504	-0.409796	-15.891340	30.269736	-61.639948	-30.195632	59.169420	-8.384824	-4.557260
0x26	-19.531304	-19.663028	10.757152	54.459716	-5.494000	-20.867892	18.984844	61.646372	26.824196	19.117792
0x27	-29.128836	-3.459292	-9.332620	17.339504	25.026592	-59.119656	54.056544	-12.055064	-21.268108	2.680656
0x28	-15.645544	-21.784092	-4.418296	-12.523804	-16.660484	74.213892	34.056316	-0.726300	51.928168	22.675180
0x29	15.689516	-11.155860	-21.276536	-14.047236	-54.493236	13.666468	-30.506112	-37.156156	43.355576	7.350436
0x2a	-29.735320	-13.753276	3.548232	31.269112	39.668368	44.830620	-6.977028	-35.663752	30.555460	4.388992
0x2b	-31.082216	11.584868	8.487652	-33.036500	-13.157316	50.502976	-23.188224	-51.524568	0.382960	-5.737796
0x2c	17.331036	-10.261824	31.780508	-23.296888	8.928572	52.597664	-44.915272	-30.676572	65.429492	36.915764
0x2d	7.656704	-12.769280	-34.288816	-46.295780	7.367804	0.185976	-26.244420	-33.013772	-69.086572	-27.984080
0x2e	-18.013668	-10.073172	3.763892	24.780428	-21.653296	4.704220	-13.278056	-57.884760	122.655536	78.080140
0x2f	-7.139380	-3.507464	-16.812212	-10.187820	11.070308	-45.039224	-26.121504	-78.043388	22.171320	17.720240

TABLE VII. Codebooks used by the LSF multi-stage quantizer for stage 4 (component values are in Hertz) - Continued.

Index	Vectors									
0x30	-0.038328	-12.205152	2.765344	43.550748	4.322620	64.041088	37.213004	30.822664	-49.288732	-32.218564
0x31	-24.910772	6.883424	-12.832696	1.845308	-52.037336	32.769556	-20.558604	73.189036	38.056292	9.735312
0x32	-1.617564	23.527380	-13.455208	32.733468	38.018240	5.814052	46.106580	49.198760	6.412352	3.359260
0x33	-22.066160	28.427852	24.169128	9.870268	22.294164	-14.262904	-2.228472	56.488580	74.734164	52.285380
0x34	20.856168	11.434760	-17.501460	19.356592	-23.927048	-10.080176	-29.157472	67.028020	-72.829380	-38.168352
0x35	4.532676	6.949228	30.519480	-1.335668	-46.754808	-16.408320	-71.551928	39.060732	-5.316548	-16.951812
0x36	-6.563488	-4.683368	-44.646952	11.974452	-5.360264	-32.144792	27.619440	35.933544	80.803460	59.884136
0x37	-12.079848	28.782912	-5.610228	32.414792	-38.174764	-53.727672	-3.846380	6.256724	29.202688	12.668764
0x38	9.128584	-15.964872	40.529996	-25.097428	-9.404020	33.634748	25.128176	67.999700	15.799964	-7.397816
0x39	-0.584244	-19.878520	15.734836	-26.676744	-33.555660	-67.913680	2.189504	28.161576	19.481028	6.669180
0x3a	27.830096	3.212196	-18.081108	-53.418624	16.337124	17.790228	-0.935908	18.558948	66.264504	36.820628
0x3b	-8.894760	17.362400	13.714624	-55.179844	3.355216	-25.666356	52.092692	9.626172	37.176688	36.454116
0x3c	24.708572	2.926604	19.614548	11.151496	-50.921244	31.058220	38.814708	9.470088	51.206496	7.702788
0x3d	26.751716	10.221092	20.453016	-38.210332	-40.726020	-25.178320	-9.964692	-19.559148	-45.512164	-28.789868
0x3e	19.678856	24.642696	-2.825972	-14.446076	-19.540088	-8.693844	1.168576	-59.036728	102.917656	79.647188
0x3f	-7.553260	16.710720	-31.982072	-28.903800	-40.696264	-28.379732	36.020044	-21.981404	-5.020000	-4.84708

TABLE VIII. Codebook used by the Fourier magnitude vector quantizer

Index	Vectors									
0x0	0.822998	1.496297	0.584847	1.313507	0.846008	0.614041	0.615298	0.881819	1.227331	0.902116
0x1	1.248150	1.020382	0.517184	1.489079	0.650498	0.716904	0.650349	1.260358	0.871024	0.907932
0x2	1.167392	1.468091	0.743322	0.712255	1.564293	0.721041	0.528277	0.657527	0.763228	0.846655
0x3	1.043080	1.570270	0.444422	0.933200	1.211773	0.669870	0.932675	0.806473	0.913787	0.868244
0x4	0.759126	1.037894	1.126967	1.133186	0.789090	0.807399	1.054906	0.949898	1.007863	1.119437
0x5	0.977225	1.130888	1.044601	1.432985	0.819888	0.517787	0.932401	0.964477	0.886867	0.895436
0x6	0.666187	1.364039	1.088940	0.902131	1.110838	0.980791	0.926721	0.867719	0.925053	0.913544
0x7	0.983185	1.460579	0.732273	0.923475	1.088579	0.952291	0.789664	1.025082	0.904670	0.854338
0x8	0.697275	1.651033	0.506420	0.809603	1.113992	1.083678	0.629739	0.986236	0.871250	0.997090
0x9	0.749416	1.354976	0.731452	1.281438	1.080946	1.037235	0.748186	0.821493	0.879839	0.965350
0xa	0.976897	2.009469	0.741592	0.606862	0.644927	0.687413	0.760360	0.833318	0.869851	0.810534
0xb	0.576891	1.527863	0.657703	1.006739	1.226803	0.786733	0.991212	0.821165	1.014984	0.878058
0xc	0.517211	1.220859	0.886556	0.980153	0.884365	1.041315	0.949276	0.881296	1.373464	0.890748
0xd	0.651809	1.106789	0.885180	1.329281	1.124388	0.626778	1.261132	0.822453	0.966925	0.806183
0xe	0.614335	1.430380	0.899696	0.847168	0.624567	1.307056	1.360741	0.735438	0.854307	0.674763
0xf	0.830604	1.373081	0.785967	0.735951	0.968745	1.100706	0.927619	0.728449	1.292031	0.884959
0x10	1.084085	1.385767	0.448480	1.297458	0.770611	0.719263	1.080766	0.909836	0.838299	0.909742
0x11	1.244608	1.158451	0.615757	1.169599	1.032735	0.921809	0.916509	1.060343	0.836990	0.767101
0x12	1.313869	1.341417	0.481710	0.685601	1.086817	1.003461	0.762127	0.832518	1.081618	0.917168
0x13	1.427137	0.932544	0.595881	0.652610	1.073852	0.847480	1.264058	0.899502	0.899264	0.958964
0x14	1.027745	1.214124	0.896291	0.972030	0.841943	0.738307	1.048254	1.077882	0.952564	1.056319
0x15	0.952252	1.098463	0.690316	1.175721	0.911712	0.962678	0.859269	1.138901	1.074558	0.924091
0x16	0.902314	1.163750	1.143587	0.814860	0.923235	0.973077	1.098871	0.966014	0.968856	0.893133
0x17	1.133879	1.110463	0.687589	0.793794	1.026535	1.076900	1.185281	0.821843	0.845464	1.079782

TABLE VIII. Codebook used by the Fourier magnitude vector quantizer - Continued.

Index	Vectors									
0x18	0.623910	1.269921	0.722072	0.990256	1.183314	1.161476	0.677381	1.199311	0.902081	0.883634
0x19	0.585861	1.189163	0.882952	1.134136	0.900218	1.263223	0.995922	1.011126	0.906268	0.863339
0x1a	0.687616	1.562003	0.815795	0.701934	0.789752	1.204232	0.821560	1.168157	0.888904	0.860778
0x1b	0.950686	1.329037	0.692678	0.754646	1.095995	1.446339	0.941535	0.710369	0.789949	0.826271
0x1c	0.520026	1.293024	0.938993	0.990412	0.897114	0.914170	1.358696	0.952011	0.936183	0.837973
0x1d	0.669622	1.291638	0.749196	1.167486	1.042641	0.721329	1.005261	1.252692	0.883186	0.854416
0x1e	0.497926	1.222508	1.403952	0.799058	0.798533	0.793545	1.264461	0.958949	0.843825	0.909886
0x1f	0.891705	1.342163	0.761635	0.758182	0.987397	1.008477	1.377249	0.845635	0.845744	0.822265
0x20	1.174305	0.454482	0.432532	0.691549	1.066271	0.890505	0.845957	1.125649	1.338280	1.204068
0x21	1.607432	0.688224	0.500617	1.288348	0.678978	0.674969	1.047764	1.012974	0.954688	0.803209
0x22	1.739179	0.919542	0.639494	0.775935	1.021945	0.991820	0.887633	0.876449	0.796800	0.771028
0x23	1.620174	1.211703	0.610139	1.372774	1.057336	0.618126	0.642995	0.667444	0.666172	0.676810
0x24	1.219952	0.844191	1.016601	0.867402	1.006595	0.940309	0.893858	0.963053	0.730414	1.286290
0x25	1.251753	1.004762	0.777132	1.203828	0.656382	0.657205	1.233246	0.874799	1.106710	0.855250
0x26	1.348819	0.791939	1.030755	0.765314	1.014939	1.044297	0.747682	1.309667	0.853913	0.723126
0x27	1.262759	1.109681	0.672002	1.109957	0.827608	1.272683	0.670943	1.068174	0.752511	0.878203
0x28	1.108504	1.250712	0.620039	0.752463	1.439216	0.890828	1.018300	0.736766	0.910504	0.849118
0x29	1.222589	1.083869	0.627894	1.150342	1.377353	0.785771	0.679900	0.897937	0.854521	0.920765
0x2a	1.326349	1.690290	1.188837	0.595281	0.602145	0.626852	0.676343	0.829212	0.785923	0.799661
0x2b	1.499772	1.400400	0.655881	0.892565	1.089036	0.702486	0.835749	0.800092	0.731263	0.835818
0x2c	1.126664	1.353291	0.898265	0.897870	0.934461	1.003119	0.982470	0.815886	0.952342	0.831774
0x2d	1.316478	1.060041	0.667653	1.065408	0.910377	1.002121	1.339044	0.710796	0.720291	0.813624
0x2e	0.976194	1.377380	1.071262	0.789567	1.085928	1.253806	1.017727	0.719049	0.561583	0.692329
0x2f	1.202869	1.059008	0.962883	0.999919	0.524897	1.074531	1.091141	0.910749	1.044517	0.859795

TABLE VIII. Codebook used by the Fourier magnitude vector quantizer - Continued.

Index	Vectors									
0x30	1.413976	0.836644	0.666408	1.039645	1.088087	0.820217	0.816371	1.049252	1.083270	0.881172
0x31	1.388093	0.807110	0.781561	0.964242	0.973557	1.138037	1.026733	0.970914	0.866461	0.841057
0x32	1.456077	0.982162	0.557993	0.738683	1.375522	0.772422	0.644426	0.952329	0.954631	1.004692
0x33	1.606208	1.220452	0.738208	0.744965	0.659231	0.813191	0.932141	0.922849	0.956161	0.892080
0x34	1.126839	1.038057	0.935449	1.012686	1.080640	0.884338	1.126468	1.076987	0.817224	0.736383
0x35	1.215351	0.845602	0.829299	1.204972	0.891515	0.934431	0.887728	0.938925	0.955741	1.114145
0x36	1.206387	0.977863	1.051199	0.847855	0.939759	1.254109	0.970361	0.901040	0.844070	0.819544
0x37	1.207602	0.976323	0.841307	0.870300	0.877422	0.988163	0.931714	1.031677	1.205409	0.903902
0x38	1.095130	1.105129	0.722843	0.943180	1.211443	1.178861	0.634252	0.870933	1.011727	0.936443
0x39	1.032014	0.998735	0.686262	1.100404	1.022352	1.222401	1.146689	0.812882	0.927129	0.801404
0x3a	1.131931	1.489739	0.677826	0.610733	0.759219	0.808122	1.042500	1.077132	1.035717	0.906736
0x3b	1.342504	1.076171	0.583400	0.764890	0.818097	1.293405	1.058200	0.852259	0.958646	0.872888
0x3c	1.308520	1.219689	0.935572	0.714861	1.129251	0.856944	0.920880	0.974834	0.821443	0.847930
0x3d	1.372592	0.887155	0.710732	1.029836	1.278897	0.650119	1.136552	0.881858	0.850047	0.819899
0x3e	1.019956	1.381944	1.089064	0.576825	0.594933	0.752016	1.265619	1.129530	0.867864	0.768122
0x3f	1.154864	1.069591	0.913967	0.796105	0.790255	0.854206	1.523905	0.856969	0.887946	0.756665
0x40	0.874806	1.645517	0.834275	1.578196	0.903996	0.547038	0.565520	0.704114	0.697290	0.713786
0x41	1.153418	1.095160	0.870564	1.655735	1.071838	0.806210	0.607539	0.566859	0.683404	0.826413
0x42	0.830864	1.448871	1.014508	0.939034	1.574030	0.796490	0.654852	0.558685	0.641596	0.797132
0x43	1.125819	1.396448	0.746324	1.295697	1.137447	1.301677	0.574765	0.486441	0.489204	0.608138
0x44	0.832614	0.802739	1.148272	1.316531	1.305743	0.696667	0.940671	0.848198	0.872696	0.851311
0x45	1.260278	0.958467	0.667246	1.406435	0.859092	0.534003	0.485425	0.723814	1.418320	0.944772
0x46	0.887527	1.330678	1.062704	0.552689	1.098956	0.917567	0.874732	1.075172	0.845710	1.019528
0x47	0.906302	1.326878	0.632127	0.781817	1.111568	0.753606	0.896250	0.945621	0.969063	1.304544
0x48	0.163798	1.616260	0.520967	1.244674	0.597986	1.174228	0.802735	1.079115	0.892800	0.877604

TABLE VIII. Codebook used by the Fourier magnitude vector quantizer - Continued.

Index	Vectors									
0x49	0.717419	1.075445	0.997204	1.206762	1.312107	1.316050	0.696587	0.745413	0.739740	0.731447
0x4a	0.339447	1.827655	0.684798	0.716559	0.676084	1.081139	0.894730	0.954454	0.948165	0.910477
0x4b	0.864667	1.451421	0.725543	1.176080	1.209637	1.083631	1.163663	0.662386	0.501862	0.463726
0x4c	0.563978	1.135516	0.835026	1.736364	1.000137	0.805360	0.828496	0.833563	0.776277	0.805186
0x4d	1.009051	1.360317	0.668259	1.417717	1.518623	0.638014	0.446922	0.496800	0.693633	0.726920
0x4e	0.186440	1.625134	0.835253	1.175778	0.860628	0.885086	1.011866	0.789303	1.010232	0.802450
0x4f	0.652311	1.599127	0.599516	1.058215	0.801753	0.992815	1.146092	0.829615	0.939228	0.837653
0x50	0.759780	1.399480	0.987329	1.024824	0.974458	0.551246	1.150852	0.844956	1.016771	0.925568
0x51	1.069814	1.160678	0.803250	1.193140	1.112463	0.744748	1.070724	0.739996	0.924675	0.942765
0x52	1.168517	1.633441	0.774778	0.736824	1.089258	1.057042	0.783527	0.691403	0.779568	0.728487
0x53	1.301817	1.572909	0.526128	0.558027	0.660410	1.078262	1.089774	0.718543	0.753433	0.965337
0x54	0.891795	1.262297	0.911545	1.214103	0.776010	0.944986	1.138773	0.772798	0.957464	0.885334
0x55	1.219015	1.048683	0.943178	1.150567	0.837824	0.566225	0.660764	1.219023	1.019092	0.988723
0x56	0.925533	1.350162	1.164350	0.542695	1.227640	0.600203	1.205779	0.701896	0.932956	0.815466
0x57	1.019130	1.292473	0.796847	0.819714	1.254208	0.522062	1.293349	0.823616	0.832862	0.890015
0x58	0.686388	1.534513	1.023273	1.065238	0.769952	0.914897	0.958226	0.965983	0.847693	0.876086
0x59	0.560425	1.321635	0.837563	1.105726	0.800833	0.952432	0.673960	1.327502	0.806885	1.135634
0x5a	0.722275	1.482196	1.269134	0.695424	0.734410	1.240968	0.873750	0.825209	0.794290	0.840055
0x5b	1.022015	1.408327	0.702067	0.966478	0.742264	1.204704	0.633885	0.888498	0.713166	1.231153
0x5c	0.512817	1.187577	0.939995	1.273059	1.261853	0.875396	0.884657	0.928591	0.900721	0.880112
0x5d	0.781537	1.223652	0.854824	0.972599	1.347144	0.807227	0.911694	0.956919	0.990262	0.893345
0x5e	0.358832	1.601542	1.125781	0.730841	0.795475	0.856229	1.070817	0.869601	1.043598	0.896567
0x5f	0.821456	1.676333	0.931807	0.740210	0.946762	0.917425	0.936539	0.884692	0.872158	0.827619
0x60	1.133434	1.069057	0.628708	1.348112	1.024242	0.726333	0.485013	0.517711	0.812878	1.483409
0x61	1.439495	0.401963	0.704352	1.185582	1.196889	0.894400	0.762308	0.871978	1.004571	0.965074

TABLE VIII. Codebook used by the Fourier magnitude vector quantizer - Continued.

Index	Vectors									
0x62	1.355857	1.217795	0.623188	0.626000	1.080819	1.443039	0.690217	0.676470	0.752167	0.890824
0x63	1.384203	0.893545	0.571820	1.422045	1.054457	0.896980	0.929532	0.779836	0.816629	0.774798
0x64	1.272930	0.807536	0.943865	1.161822	1.109685	0.883353	0.756987	1.183318	0.792499	0.818768
0x65	1.368426	0.939970	0.927314	1.372501	0.966845	0.661820	0.817570	0.813094	0.874638	0.905751
0x66	1.234512	0.812394	1.092298	0.956999	0.926831	1.159350	0.560790	0.914404	1.104409	0.951357
0x67	1.462063	1.107453	0.736919	1.182041	0.753060	0.817381	0.845724	0.960321	0.930034	0.870101
0x68	1.154263	1.149050	0.969239	1.003195	0.709246	1.334899	0.539388	0.648414	1.170228	0.841587
0x69	1.363427	0.856319	0.848329	1.330223	1.580245	0.593904	0.534564	0.577523	0.647285	0.799871
0x6a	1.430748	1.277622	0.535910	1.316419	0.704018	1.139968	0.844730	0.708186	0.689915	0.673166
0x6b	1.456831	0.852769	0.836842	1.661979	0.555156	0.659789	0.754965	0.765223	0.801905	0.871901
0x6c	1.219340	0.941999	1.021315	1.258016	0.869648	1.086416	1.006363	0.806097	0.807889	0.739562
0x6d	1.269435	1.217910	1.091920	1.130622	1.241678	0.548636	0.659441	0.769661	0.738142	0.844145
0x6e	1.109102	1.109600	0.921873	1.080103	0.644065	1.551581	0.917328	0.782032	0.649409	0.682361
0x6f	1.148823	1.115256	0.784950	1.519787	0.632186	0.880947	0.965093	0.738516	0.923041	0.843738
0x70	1.099162	1.072237	1.059239	1.012868	1.091543	0.820111	0.632757	0.796845	1.140959	1.032531
0x71	1.382078	1.014650	0.855020	1.088445	1.147617	1.054602	0.759230	0.758359	0.828497	0.830315
0x72	1.331108	0.911897	0.551680	0.739304	1.080511	1.173246	0.671436	0.925538	1.082333	1.110124
0x73	1.380841	1.130295	0.743747	0.910074	0.957719	0.986217	0.885270	0.809240	0.914088	1.051811
0x74	1.310270	0.998818	0.989857	1.025202	0.906801	0.876459	0.895856	0.981348	0.982188	0.901957
0x75	1.442392	0.947518	1.052543	0.888925	1.092888	0.674498	0.920650	0.987177	0.890263	0.816537
0x76	1.173251	0.879037	1.128982	0.905439	1.302826	1.072854	0.709855	0.689286	1.000834	0.819403
0x77	1.162547	0.939193	1.038151	0.930689	0.914292	0.877584	1.144403	0.667857	1.257437	0.810249
0x78	0.957634	1.145630	1.008914	1.045813	1.030746	1.071616	0.801657	0.909400	0.880216	1.014015
0x79	1.250553	1.148173	0.606277	0.991795	0.997859	0.688890	0.942568	0.922857	1.233180	0.891771
0x7a	1.223899	1.343365	0.813470	0.600631	0.514261	1.292102	0.994158	1.012705	0.774822	0.889761

TABLE VIII. Codebook used by the Fourier magnitude vector quantizer - Continued.

Index	Vectors									
0x7b	1.434258	1.190874	0.478282	0.454840	0.731792	1.170314	0.776934	1.201793	0.865726	0.993823
0x7c	1.075483	0.950940	1.056806	0.939311	0.767863	1.050672	0.923138	1.208091	0.957328	0.914622
0x7d	1.152850	0.985329	0.758860	0.902903	1.268339	0.822622	0.951593	0.972154	0.988798	1.010038
0x7e	0.934316	1.213602	1.137776	0.530840	0.583216	1.327735	0.648220	1.122533	0.983140	0.947688
0x7f	1.096461	1.329950	1.056696	1.096312	0.518753	0.667957	1.377914	0.802439	0.713627	0.728387
0x80	0.438479	0.986558	0.795180	1.048475	1.212747	1.336801	0.859633	1.040980	0.943136	0.921149
0x81	1.106514	0.482598	0.612108	1.642264	0.798236	0.780622	0.825869	0.883680	1.122055	0.975218
0x82	0.977340	0.929082	0.748423	0.688517	1.866792	0.978102	0.704420	0.691328	0.814419	0.732273
0x83	2.061007	1.317233	0.531080	0.663650	0.466228	0.673965	0.663756	0.680624	0.722060	0.735546
0x84	0.324483	0.566419	1.626532	0.909957	0.767043	1.218518	0.923857	0.781191	1.034489	0.929690
0x85	1.132776	0.664024	0.658276	1.115888	1.058611	0.773592	1.143017	1.345343	0.885859	0.793138
0x86	0.693193	0.957946	1.074530	0.991271	1.178869	1.050262	1.231718	0.919607	0.838514	0.820971
0x87	0.981206	1.282808	0.628439	0.831905	0.871888	1.000360	1.072068	1.359583	0.865264	0.714229
0x88	0.444708	1.320901	0.863009	0.823633	1.282252	1.175766	1.016159	0.800445	0.885734	0.918392
0x89	0.524278	0.903183	0.842282	0.999358	1.663203	0.862494	0.990065	0.863742	0.861246	0.885159
0x8a	0.647517	1.630489	0.674425	0.552789	1.367019	0.802523	1.078554	0.810538	0.843750	0.824923
0x8b	1.157635	1.168651	0.661005	0.556302	1.240422	0.970912	0.829631	1.237884	0.917322	0.831318
0x8c	0.271398	0.978008	0.699287	1.501347	0.903792	1.105029	0.960131	1.036695	1.001109	0.890359
0x8d	0.275143	0.628587	1.143603	1.112293	1.315251	1.071179	0.889841	0.954181	1.018312	0.964080
0x8e	0.659209	1.447333	0.894087	1.001992	0.839399	1.449942	0.796803	0.843993	0.756016	0.817636
0x8f	0.853138	1.064738	0.855133	0.742170	0.868512	1.370756	0.989681	1.038327	0.937196	0.993200
0x90	0.973539	1.188932	1.023116	0.931037	1.059522	0.699512	0.709015	1.360161	0.889684	0.811761
0x91	1.226588	1.022695	0.719215	1.364611	0.676914	0.710196	1.255418	1.207082	0.643748	0.569250
0x92	0.911359	1.344114	1.042414	0.518823	1.545711	0.394875	0.583463	1.042424	0.973970	0.781663
0x93	1.728382	0.630457	0.384633	0.410263	0.623340	0.756137	0.963416	1.240436	1.179740	0.957703

TABLE VIII. Codebook used by the Fourier magnitude vector quantizer - Continued.

Index	Vectors									
0x94	0.738959	0.590931	1.110580	1.101743	0.983178	0.969963	1.084357	1.136055	1.021410	0.944931
0x95	1.244427	0.569958	1.057313	1.369461	0.723367	0.805159	1.027868	1.091877	0.873967	0.776658
0x96	0.787743	0.905228	1.203273	0.843008	1.182612	1.029414	0.763719	1.097128	0.900016	1.016990
0x97	1.314427	1.012982	0.695385	0.878737	0.749022	0.792771	1.048592	1.421864	0.816344	0.837093
0x98	0.284264	1.037450	0.783668	1.045137	1.085681	0.925955	1.010468	0.963587	1.285465	1.083612
0x99	0.182413	0.501944	0.613194	0.864945	1.046530	1.201125	1.222115	1.201816	1.144754	1.100226
0x9a	0.399720	1.302627	1.339572	0.544091	1.113712	0.704227	0.959569	1.086265	0.919326	0.996120
0x9b	1.312087	1.234779	1.155127	0.573204	0.603170	1.675500	0.578462	0.549438	0.586763	0.627105
0x9c	0.347498	1.019206	0.902255	0.918363	1.078096	0.895444	1.295650	1.236476	0.896594	0.955950
0x9d	0.228297	0.547356	1.316811	1.334579	0.850478	0.739122	1.162684	1.153175	0.961239	0.847730
0x9e	0.450951	1.164991	1.356497	0.748838	1.098313	1.180630	0.960353	0.882357	0.871493	0.801907
0x9f	1.101005	1.177952	1.577841	0.463778	0.535020	0.573959	0.857461	1.214102	0.824723	0.827632
0xa0	1.008192	0.512187	0.511630	0.803656	1.363784	1.397129	1.041883	0.945399	0.880500	0.836761
0xa1	1.333032	0.522169	0.512363	0.626419	0.780427	0.951713	1.495366	1.235918	0.888195	0.836141
0xa2	1.680621	0.528954	0.445504	0.623836	1.316133	1.053039	0.890863	0.877480	0.775161	0.883213
0xa3	2.235511	0.589895	0.429925	0.577054	0.680209	0.667395	0.784315	0.803936	0.861809	0.801209
0xa4	1.092796	0.555938	1.481165	0.731586	1.165349	0.972450	0.847847	0.832928	0.893096	0.925555
0xa5	1.276456	0.719658	0.981702	1.037082	1.176864	0.684247	0.782879	0.891723	1.117659	1.034450
0xa6	1.228245	0.771626	1.121788	0.749934	0.884593	0.958108	1.233677	1.045060	0.933820	0.833295
0xa7	1.469187	0.712424	0.977325	0.707326	1.237597	0.953937	0.835168	0.794138	0.991406	0.934207
0xa8	1.079164	1.065143	1.263724	0.575489	1.628970	0.516204	0.546497	0.527023	0.774807	1.079119
0xa9	1.337945	0.994695	0.675169	0.865744	1.373516	1.324911	0.866779	0.633895	0.599425	0.727921
0xaa	1.511212	0.641169	1.710560	0.731522	0.590315	0.546117	0.624898	0.778970	0.908906	0.903649
0xab	1.760845	1.236091	1.067203	0.487204	0.655720	0.713362	0.697764	0.749475	0.847174	0.921298
0xac	1.242002	1.065400	0.986706	0.626575	1.306310	0.681929	0.717473	0.615010	1.350818	0.832838

TABLE VIII. Codebook used by the Fourier magnitude vector quantizer - Continued.

Index	Vectors									
0xad	1.114715	0.651334	1.082160	1.095767	1.064034	1.122643	1.004475	0.903535	0.874168	0.865362
0xae	1.244497	1.005714	1.193496	0.734583	0.598761	1.274922	1.289539	0.614727	0.688696	0.778442
0xaf	1.408250	0.839767	1.067828	0.572007	0.672582	1.239141	0.865001	0.858314	1.080318	0.941161
0xb0	1.250488	0.918235	1.101326	0.668242	1.365644	0.555295	0.552784	1.259466	0.907460	0.811412
0xb1	1.631045	0.643427	0.448596	0.462433	0.721966	1.376064	1.149863	0.918544	0.813496	0.874574
0xb2	1.535075	1.109493	1.002904	0.867410	1.515072	0.754291	0.569348	0.512821	0.594932	0.664862
0xb3	1.968050	0.717136	1.151858	0.741070	0.764881	0.686026	0.715694	0.699206	0.765000	0.778737
0xb4	1.413788	0.795490	1.377022	0.733397	1.230761	0.728025	0.815985	0.866154	0.713555	0.821627
0xb5	1.339077	0.710095	1.014431	1.092420	0.988468	0.688934	1.213969	0.865531	0.928889	0.852068
0xb6	1.172569	0.971105	1.147345	0.503528	1.077878	1.006880	0.936191	1.024685	0.978125	0.897520
0xb7	1.346133	0.825702	1.278602	0.712776	0.990801	0.824307	0.741063	0.777009	1.172757	0.958583
0xb8	0.838360	1.061588	1.184451	0.806865	1.445930	0.716610	1.122729	0.763437	0.824729	0.830950
0xb9	1.276108	0.881797	1.013445	0.821855	1.264900	1.025945	1.227647	0.703569	0.659312	0.734361
0xba	1.043635	1.011762	1.513310	0.739962	0.660585	0.587323	0.680578	0.841721	1.167268	1.132996
0xbb	1.473979	0.627258	1.381177	0.659284	0.759202	1.049849	1.020305	0.870139	0.779335	0.834162
0xbc	1.308547	0.926336	1.119570	0.550398	1.232051	0.605843	1.181402	0.819554	0.865953	0.920083
0xbd	1.337645	0.769449	1.229177	0.813618	0.735630	0.883470	1.569295	0.634285	0.606052	0.688148
0xbe	1.290794	1.093894	1.145434	0.552063	0.804350	0.769436	0.840595	1.089482	1.009731	1.051359
0xbf	1.364932	0.913519	1.316632	0.718362	0.529225	0.723872	1.181281	0.876150	0.962565	0.918262
0xc0	0.803741	1.388152	0.980932	1.386743	0.402886	1.229764	0.855613	0.743859	0.738745	0.812385
0xc1	1.187083	1.328233	0.750736	1.808456	0.498683	0.428506	0.498878	0.815022	0.756569	0.712230
0xc2	1.008780	1.634667	0.998899	1.114864	1.106568	0.814867	0.677242	0.626767	0.727848	0.701162
0xc3	1.442123	1.578969	1.235055	1.279799	0.604508	0.459123	0.486663	0.548079	0.537477	0.639041
0xc4	0.824699	0.832512	1.286809	0.946005	0.788899	1.581450	0.819352	0.804348	0.757910	0.797158
0xc5	1.173084	0.852089	0.837159	1.215371	0.614107	0.664921	0.798941	1.185092	1.404650	0.752108

TABLE VIII. Codebook used by the Fourier magnitude vector quantizer - Continued.

Index	Vectors									
0xc6	0.837980	1.195548	1.251800	1.166862	1.139151	0.630036	0.966812	0.823920	0.819578	0.833867
0xc7	1.284059	1.360185	0.903226	1.260066	0.869280	0.794052	0.767674	0.784999	0.770146	0.814413
0xc8	0.434909	1.062061	0.820721	0.980006	0.915903	1.352711	1.363232	0.818512	0.933755	0.804752
0xc9	0.140705	0.369673	0.761460	1.721146	1.281940	0.814390	0.770430	0.912685	1.029093	0.894100
0xca	0.381833	1.386068	0.895360	0.756433	0.795777	0.665474	1.098763	1.438104	1.037485	0.828884
0xcb	0.848084	1.088554	0.824684	0.776900	0.721938	0.676660	0.800316	1.135752	1.511374	1.057070
0xcc	0.675218	1.083363	1.015844	1.396638	0.903676	0.983177	0.888414	1.062584	0.890620	0.821218
0xcd	0.754970	0.952752	1.127383	1.539338	0.700672	0.751028	0.640102	0.797817	1.188132	0.971816
0xce	0.701999	1.321737	1.118923	1.317673	0.798997	1.146361	0.653062	0.923909	0.716226	0.881342
0xcf	0.916108	1.387334	0.769658	1.200061	0.617306	1.096865	0.828575	1.077143	0.950269	0.767253
0xd0	0.662335	1.292372	1.294051	1.134329	0.611097	0.878492	0.979876	0.932184	0.972586	0.870668
0xd1	1.081800	1.056505	1.431825	1.568379	0.608668	0.601313	0.533137	0.646402	0.768233	0.839110
0xd2	1.062379	1.439992	1.195124	1.101291	0.690349	0.686199	0.744970	0.782839	0.947571	0.913290
0xd3	1.302173	1.079498	1.059178	0.961715	0.721412	0.548559	0.490001	0.649919	1.527619	0.917298
0xd4	0.680923	1.193324	1.324460	1.076160	0.940757	1.158478	1.016504	0.799201	0.766968	0.708056
0xd5	1.013158	0.953016	1.286560	1.218908	0.634730	1.131540	0.788277	0.928104	0.871793	0.842399
0xd6	0.801060	0.948640	1.501946	0.737009	0.751623	1.024697	1.091762	0.879438	0.970670	0.874395
0xd7	1.322228	1.272781	1.083638	0.879445	0.649796	0.924154	0.851784	0.949572	0.890756	0.876190
0xd8	0.308295	1.165975	1.273902	1.153456	0.938787	0.761951	0.988352	0.937937	0.984994	0.988803
0xd9	0.307028	0.833986	1.891761	1.166166	0.526468	0.545358	0.772629	0.838092	0.849941	1.006412
0xda	0.724400	1.661022	1.407543	0.659395	0.621709	0.664584	0.781703	0.915312	0.912252	0.868291
0xdb	0.899730	0.520003	2.050203	0.570193	0.525624	0.618870	0.773975	0.953262	0.860057	0.852288
0xdc	0.564036	1.194072	1.054038	1.309234	0.682175	1.184083	1.261020	0.720925	0.837966	0.682236
0xdd	0.705321	0.906931	1.440192	1.246568	0.945792	0.911725	0.914322	0.903469	0.819844	0.853160
0xde	0.639259	1.118893	1.183435	0.912825	0.722814	1.107206	0.903505	1.289695	0.937470	0.852877

TABLE VIII. Codebook used by the Fourier magnitude vector quantizer - Continued.

Index	Vectors									
0xdf	0.833210	1.220093	1.668781	0.922503	0.998916	0.696036	0.765626	0.779931	0.724635	0.754248
0xe0	1.214346	0.962383	1.132890	0.827035	0.876470	1.255731	0.611676	0.550693	0.663031	1.355367
0xe1	1.790710	0.452581	0.576174	0.955171	0.930091	0.858695	1.025674	0.874218	0.875633	0.842868
0xe2	1.436801	0.888196	1.189311	0.679367	1.104152	1.351368	0.585875	0.677641	0.703740	0.775152
0xe3	1.614636	0.783579	0.883180	1.156453	0.973477	0.848164	0.830311	0.892666	0.763745	0.831350
0xe4	1.372060	0.499597	1.000811	0.900767	0.931695	0.898965	1.028259	1.067040	0.960141	0.995706
0xe5	1.464549	0.744441	0.906385	0.936059	0.731646	0.716360	0.829522	1.117880	1.156979	1.018394
0xe6	1.367898	0.866499	1.263666	1.112268	1.167850	0.937974	0.788936	0.718079	0.635187	0.707080
0xe7	1.439445	0.795863	0.796972	1.211896	0.538767	1.255454	0.958684	0.857981	0.848545	0.824913
0xe8	1.376381	0.568678	0.926291	0.641770	0.834535	1.808678	0.804428	0.607970	0.669675	0.720965
0xe9	1.355563	0.460449	0.596175	1.214770	0.946022	1.352957	0.860313	0.864696	0.785836	0.918103
0xea	1.435024	0.909544	1.041289	1.123733	0.794294	1.439099	0.648301	0.574374	0.602775	0.780902
0xeb	1.516270	0.918985	0.927275	1.189389	0.590144	0.748748	1.248918	0.683386	0.755543	0.882486
0xec	1.476744	0.514611	1.218581	1.065365	0.862836	0.922786	0.764142	0.839729	0.935193	0.933221
0xed	1.315547	0.722841	1.311024	1.315785	0.913893	0.706439	0.682783	0.788285	0.877441	0.888931
0xee	1.348712	0.858988	1.055635	1.052220	0.611431	1.171928	0.730139	1.115700	0.744873	0.946277
0xef	1.180305	1.053248	0.878721	1.288189	0.507336	1.103290	0.705925	1.007651	0.841461	1.044969
0xf0	1.196638	1.080029	1.301461	0.997280	0.885975	0.846955	0.887870	0.844710	0.873575	0.870310
0xf1	1.373492	1.068929	1.077698	1.096515	0.998252	0.717247	1.234505	0.694028	0.663647	0.627234
0xf2	1.437332	1.207382	1.145016	0.902884	0.999814	1.049959	0.751617	0.679969	0.707880	0.681629
0xf3	1.540923	0.966825	1.074880	0.967647	0.780575	0.824665	0.721806	0.771586	0.917974	1.059911
0xf4	1.075058	0.874560	1.223286	0.875247	1.114946	0.785841	1.030228	1.006401	0.939058	0.894774
0xf5	1.230599	0.763269	1.223421	1.021346	0.751078	0.863709	0.928759	0.989248	1.037576	0.975537
0xf6	1.200394	0.826452	1.374917	0.728714	0.749645	1.169742	0.809933	1.098679	0.840553	0.806698
0xf7	1.458186	0.835033	1.120633	0.933190	0.831612	1.053974	1.060913	0.785122	0.845646	0.769115

TABLE VIII. Codebook used by the Fourier magnitude vector quantizer - Continued.

Index	Vectors									
0xf8	1.087334	1.237373	1.295267	0.657919	1.094758	1.035074	0.693941	0.869327	0.868297	0.787626
0xf9	1.183917	0.792976	1.143049	0.749982	0.626687	0.658678	0.983599	1.416025	1.044253	0.931234
0xfa	1.694116	1.108393	1.504700	0.828677	0.586589	0.658925	0.648047	0.676080	0.628926	0.681370
0xfb	1.363659	0.859205	1.134321	1.227826	0.519545	0.570781	0.847817	1.035284	0.967904	0.993060
0xfc	1.202407	0.995001	1.034142	0.944991	0.778536	0.657893	1.164819	0.964661	0.913810	1.114029
0xfd	1.325400	0.953743	1.087893	1.003095	0.754906	0.862034	1.119859	1.201467	0.736865	0.616466
0xfe	1.321790	0.767809	1.313064	0.954328	0.816200	0.607967	0.663671	1.355803	0.816644	0.850276
0xff	1.493994	1.117090	1.211209	1.311853	0.619853	0.708056	0.764515	0.708914	0.718302	0.743372

APPENDIX A

MELP ALGORITHM DESCRIPTION

A.1 SCOPE

A.1.1 Scope. This appendix provides a complete description of a MELP algorithm. This appendix is not a mandatory part of this standard. The information contained herein is intended for guidance only.

A.2 APPLICABLE DOCUMENTS

A.2.1 Government documents. The documents in 2. of this standard apply to this appendix.

A.2.2 Other publications. The following documents form a part of this appendix to the extent specified.

INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS (IEEE)

"A Mixed Excitation LPC Vocoder Model for Low Bit Rate Speech Coding" by A.V. McCree and T.P. Barnwell III, Transactions on Speech and Audio Processing, Vol. 3, No. 4, July 1995, 242-250

"A 2.4 kbits/s MELP Coder Candidate for the New U.S. Federal Standard" by A. McCree, K. Truong, E.B. George, T.P. Barnwell III, and V. Viswanathan, Proceedings of IEEE ICASSP 1996, pp.200-203

"Super Resolution Pitch Determination of Speech Signals" by Y. Medan, E. Yair, and D. Chazan, Transactions on Signal Processing, Vol. 39, No. 1, January 1991, pp. 40-48

"The Computation of Line Spectral Frequencies Using Chebyshev Polynomials" by P. Kabal and R.P. Ramachandran, Transactions on Acoustics, Speech, and Signal Processing, Vol. ASSP-34, No.6, December 1986, pp.1419-1426

"Efficient Search and Design Procedures for Robust Multi-Stage VQ of LPC Parametersfor 4 kb/s Speech Coding" by W.P. LeBlanc, B. Bhattacharya, S.A. Mahmoud, and V. Cuperman, Transactions on Speech and Audio Processing, Vol. 1, No. 4, October 1993, pp. 373-385

"New Methods for Adaptive Noise Supression" by L. Arslan, A. McCree, and V. Viswanathan, Proceedings of IEEE ICASSP 1995, pp. 812-815

"MELP: The New Federal Standard at 2400 BPS" by L. Supplee, R. Cohn, J. Collura, A. McCree, Proceedings of IEEE ICASSP 1997, pp. 1591-1594

(Applications for copies should be addressed to IEEE Customer Service, 445 Hoes Lane, P.O. Box 1331 Piscataway, New Jersey 08855-1331, USA)

APPENDIX A

A.2.3 Order of precedence. In the event of a conflict between the text of this standard and the references stated herein, the text of this standard should take precedence.

A.3 DEFINITIONS

A.3.1 Terms. The definitions in 3.1 of this standard apply to this appendix.

A.3.2 Acronyms. The acronyms used is this appendix are defined in 3.2 or as follows:

DC - Direct Current

DFT - Discrete Fourier Transform

FFT - Fast Fourier Transform

FIR - Finite Impulse Response

RMS - Root Mean Square

VQ - Vector Quantization

A.4 GENERAL REQUIREMENTS

Not applicable.

A.5 DETAILED REQUIREMENTS

A.5.1 General. The Mixed Excitation Linear Prediction coder is based on the traditional Linear Prediction Coding (LPC) parametric model, but also includes five additional features. These are: mixed excitation, aperiodic pulses, adaptive spectral enhancement, pulse dispersion, and Fourier magnitude modeling. These features are illustrated in the MELP decoder block diagram shown in Figure A-1.

The mixed excitation is implemented using a multi-band mixing model. This model can simulate frequency-dependent voicing strength using an adaptive filtering structure implemented with a fixed filter bank. The primary effect of this mixed excitation is to reduce the buzz usually associated with LPC vocoders, especially in broadband acoustic noise.

When the input speech is voiced, the MELP coder can synthesize using either periodic or aperiodic pulses. Aperiodic pulses are used most often during transition regions between voiced and unvoiced segments of the speech signal. This feature enables the decoder to reproduce erratic glottal pulses without introducing tonal sounds.

The adaptive spectral enhancement filter is based on the poles of the linear prediction synthesis filter. Its use enhances the formant structure of the synthetic speech and improves the match between the synthetic and natural bandpass waveforms. It also gives the synthetic speech a more natural quality.

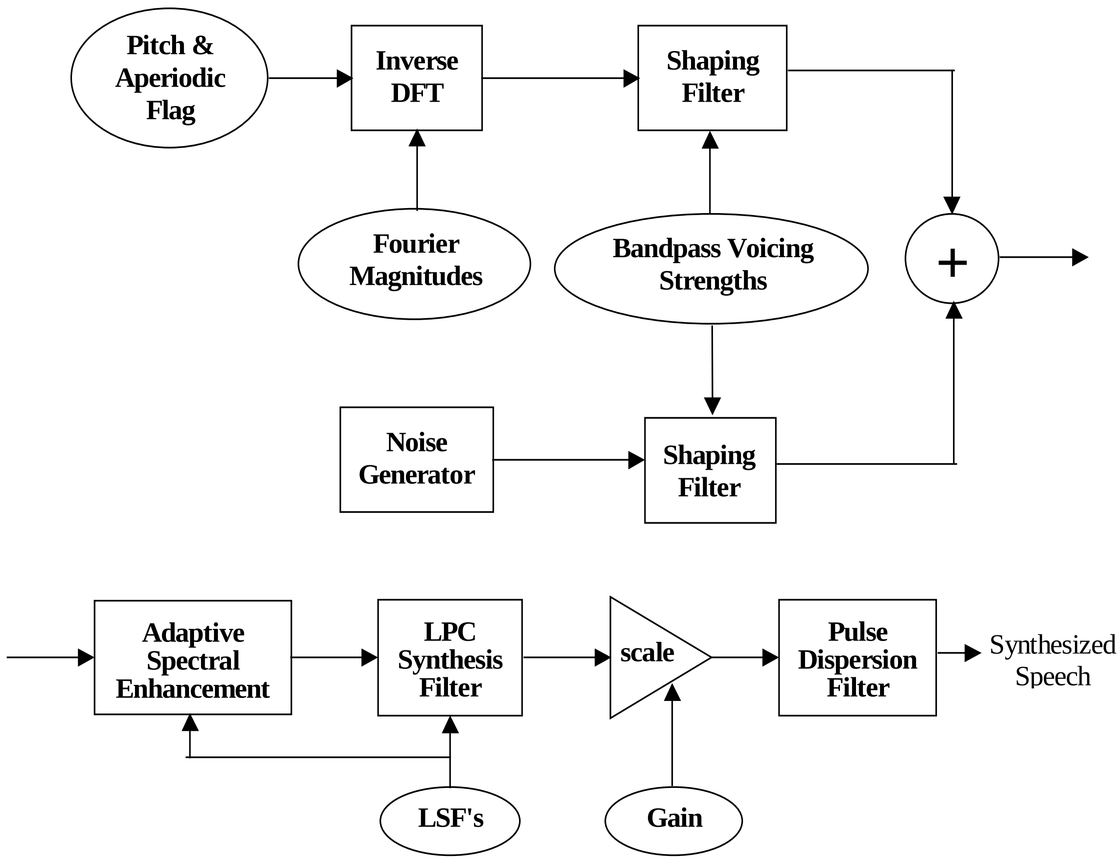

Figure A- 1. MELP decoder block diagram.

Pulse dispersion is implemented using a fixed filter based on a spectrally-flattened triangle pulse. This filter spreads the excitation energy within a pitch period, reducing some of the harsh quality of the synthetic speech.

The first ten Fourier magnitudes are determined from the peaks of the Fourier transform of the prediction residual signal. The information in these coefficients improves the accuracy of the speech production model at the perceptually-important lower frequencies. This increases the quality of the synthetic speech, particularly for male speakers and when background noise is present.

A.5.2 Encoder. Input speech is encoded by performing the following steps in the order given.

A5.2.1 Low frequency removal. The first step in the encoding process is to remove any low frequency energy which may be present in the input signal. This is accomplished with a 4th order Chebychev type II highpass filter, having a cutoff frequency of 60 Hz and a stopband rejection of 30 dB. The filter output is referred to as the input speech signal throughout the following encoder description.

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A buffer containing the most recent samples of the input speech signal is maintained in the encoder. One of these samples is designated the last sample in the current frame. The buffer extends beyond this sample into the past and future to contain the samples needed for the encoding process. The last sample in the current frame serves as a reference point for many of the encoder calculations.

A5.2.2 Integer pitch calculation. For this pitch calculation, the input speech signal is first processed with a 1 kHz, 6th order Butterworth lowpass filter. The integer pitch value, P_1, is the value of , τ, $\tau = 40,41,...,160$, for which the normalized autocorrelation function, $r(\tau)$, is maximized. This function is defined by:

$$r(\tau) = \frac{c_\tau(0,\tau)}{\sqrt{c_\tau(0,0)c_\tau(\tau,\tau)}}$$, **EQUATION A-1**,

where $c_\tau(m,n) = \sum_{k=-\lfloor \tau/2 \rfloor-80}^{-\lfloor \tau/2 \rfloor+79} s_{k+m}s_{k+n}$, **EQUATION A-2**,

and $\lfloor \tau/2 \rfloor$ represents truncation to an integer value. The center of the pitch analysis window is at sample s_0 in equation A-2. For the integer pitch calculation, this window is centered on the last sample in the current frame. The lowpass filter output is sample s_0 when its input is the last sample in the current frame. The time index k in the autocorrelation preserves the pitch analysis window alignment around its center point; the normalization compensates for changing signal amplitudes. The final pitch calculation (see A5.2.9) extends the pitch range to a lag of 20 samples.

A5.2.3 Bandpass voicing analysis. This portion of the encoder determines the five bandpass voicing strengths, $\mathrm{Vbp}_i, i = 1,2,...,5$. It also refines the integer pitch measurement and the corresponding normalized autocorrelation value. The bandpass voicing analysis begins by filtering the input speech signal into five frequency bands. These filters are 6th order Butterworth, with passbands of 0-500, 500-1000, 1000-2000, 2000-3000, and 3000-4000 Hz.

A refined pitch measurement is made using the 0-500 Hz filter output signal. This measurement is centered on the filter output produced when its input is the last sample in the current frame. Two pitch candidates are considered in this refinement, namely the integer pitch values, P_1 , from the current and previous frames. For each candidate, equation A-1 is used to perform an integer pitch search over lags from 5 samples shorter to 5 samples longer than the candidate, and a fractional pitch refinement (see A5.2.4) is performed around the optimum integer pitch lag. This produces two fractional pitch candidates and their corresponding normalized autocorrelation values. The candidate having the higher normalized autocorrelation is selected as the fractional pitch, P_2 . The corresponding normalized autocorrelation, $r(P_2)$, is saved as the lowest band voicing strength, Vbp_1 . P_2 is saved for use in determining the voicing strength for the remaining frequency bands. It is also used in the final pitch calculation (see A5.2.9) and gain calculation (see A5.2.11).

For each remaining band, the bandpass voicing strength is the larger of $r(P_2)$ as determined by the fractional pitch procedure for the bandpass signal and the time envelope of the bandpass signal, where $r(P_2)$ for the time envelope is first decremented by 0.1 to compensate for an experimentally observed bias (due to the smoothness of the time envelope signals). The envelopes are calculated by full-wave rectification followed by a smoothing filter. This filter consists of a zero at DC in cascade with a complex pole pair at 150 Hz with a radius of 0.97. For each calculation of $r(P_2)$, the analysis window is centered on the last sample in the current frame, as was the case for the first band.

A5.2.4 Fractional pitch refinement. This procedure, which is used at several places in the encoding process, utilizes an interpolation formula to increase the accuracy of an input pitch value. This value is first rounded to the nearest integer. Assume that this integer has a value of T samples. The interpolation formula presumes that $r(\tau)$ has a maximum between lags of T and T+1. Hence, $c_T(0,T-1)$ and $c_T(0,T+1)$ are computed and compared to determine if the maximum is more likely to fall between *T* and *T*+1 or between T-1 and T. If $c_T(0,T-1) > c_T(0,T+1)$, then the maximum probably falls between T-1 and T and the pitch, T, is decremented by one prior to interpolation. The fractional offset, Δ, is then computed by the interpolation equation:

$$\Delta = \frac{c_T(0,T+1)c_T(T,T) - c_T(0,T)c_T(T,T+1)}{c_T(0,T+1)[c_T(T,T) - c_T(T,T+1)] + c_T(0,T)[c_T(T+1,T+1) - c_T(T,T+1)]}$$,**EQUATION A-3**,

where $c_T(m,n)$ is defined by equation A-2. In some cases, this formula produces an offset outside the range of 0.0 to 1.0, so the offset is clamped between -1 and 2. The fractional pitch is $T+\Delta$ and is clamped between 20 and 160.

The normalized autocorrelation at the fractional pitch value is given by:

$$r(T+\Delta) = \frac{(1-\Delta)c_T(0,T) + \Delta c_T(0,T+1)}{\sqrt{c_T(0,0)\left[(1-\Delta)^2 c_T(T,T) + 2\Delta(1-\Delta)c_T(T,T+1) + \Delta^2 c_T(T+1,T+1)\right]}}$$, **EQUATION A-4**.

Equations A-3 and A-4 produce the fractional offset and corresponding normalized autocorrelation which would be obtained if the input signal had been linearly interpolated to obtain values between the actual sampling times.

A5.2.5 Aperiodic flag. The aperiodic flag is set to 1 if $Vbp_1 < 0.5$ and set to 0 otherwise. The Vbp_1 value determined by bandpass voicing analysis (see A5.2.3) is used for this comparison. When set, this flag tells the decoder that the pulse component of the excitation should be aperiodic, rather than periodic. A5.3.1 describes the use of the aperiodic flag.

A5.2.6 Linear prediction analysis. A 10^{th} order linear prediction analysis is performed on the input speech signal using a 200 sample (25 ms) Hamming window centered on the last sample in the current frame. The traditional autocorrelation analysis procedure is implemented using the Levinson-Durbin recursion. In addition, a bandwidth expansion coefficient of 0.994 (15 Hz) is applied to the prediction coefficients, a_i, $i = 1,2,...,10$, where each coefficient is multiplied by 0.994^i.

A5.2.7 Linear prediction residual calculation. The linear prediction residual signal is calculated by filtering the input speech signal with the prediction filter whose coefficients were determined by linear prediction analysis (see A5.2.6). The residual window is centered on the last sample in the current frame, and is made wide enough for use by the final pitch calculation (see A5.2.9).

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A5.2.8 Peakiness calculation. The peakiness of the residual signal is calculated over a 160 sample window centered on the last sample in the current frame. The peakiness value is the ratio of the L2 norm to the L1 norm of the residual signal, r_n, in the window:

$$\text{peakiness} = \frac{\sqrt{\frac{1}{160}\sum_{n=1}^{160} r_n^2}}{\frac{1}{160}\sum_{n=1}^{160} |r_n|}, \textbf{ EQUATION A-5}.$$

If the peakiness exceeds 1.34, then the lowest band voicing strength, Vbp_1, is forced to 1.0. If the peakiness exceeds 1.6, then the lowest three band voicing strengths, $Vbp_i, i = 1,2,3$, are all forced to 1.0. This is the only use of the peakiness measure.

A5.2.9 Final pitch calculation. The final pitch measurement uses the lowpass filtered residual signal, where the filter is a 6th order Butterworth, with a 1 kHz cutoff. Equation A-1 is used to perform an integer pitch search over lags from 5 samples shorter to 5 samples longer than P_2, rounded to the nearest integer. This measurement is centered on the filter output produced when its input is the last residual sample in the current frame. A fractional pitch refinement (see A5.2.4) is then made around the optimum integer pitch lag. This produces tentative values for the final pitch, P_3, and for the corresponding normalized autocorrelation, $r(P_3)$.

If $r(P_3) \geq 0.6$, the pitch doubling check procedure (see A5.2.10) is performed on the filtered residual, using P_3 as the candidate pitch, and doubling threshold $D_{th} = 0.75$ if $P_3 \leq 100$, or $D_{th} = 0.5$ otherwise. The doubling check procedure may produce new values for P_3 and $r(P_3)$.

The else action for the preceding if is as follows. A fractional pitch refinement around P_2 is performed using the input speech signal. This measurement is centered on the last sample in the current frame and produces new values for P_3 and $r(P_3)$. If $r(P_3) < 0.55$, then P_3 is replaced by P_{avg}, the long-term average pitch (see A5.2.12). Otherwise, the pitch doubling check procedure is performed on the input speech signal, using P_3 as the candidate pitch, and doubling threshold $D_{th} = 0.9$ if $P_3 \leq 100$, or $D_{th} = 0.7$ otherwise. The doubling check procedure may produce new values for P_3 and $r(P_3)$.

Finally, if $r(P_3) < 0.55$, then P_3 is replaced by P_{avg}.

The following pseudo code shows the final pitch algorithm:

```
inputs: the input speech signal; the residual signal; P2; Pavg
outputs: P3, cor_P3

fresid buffer = filter the residual with a 1 kHz Butterworth
P3 = best integer pitch on fresid over the range P2-5 to P2+5
P3, cor_P3 = frac_pitch(fresid, P3)
if (cor_P3 >= 0.6)
```

```
        Dth = 0.5
        if (P3 <= 100) Dth = 0.75
        P3, cor_P3 = double_ck(fresid, P3, Dth)
    else
        P3, cor_P3 = frac_pitch(input, P2)
        if (cor_P3 < 0.55)
            P3 = Pavg
        else
            Dth = 0.7
            if (P3 <= 100) Dth = 0.9
            P3, cor_P3 = double_ck(input, P3, Dth)
        endif
    endif
    if (cor_P3 < 0.55) P3 = Pavg
```

A5.2.10 Pitch doubling check. The pitch doubling check procedure looks for and corrects pitch values which are multiples of the actual pitch. This procedure takes a signal, a candidate pitch P, and a doubling threshold D_{th}, and returns the checked pitch P_c, and the corresponding correlation, $r(P_c)$. All fractional pitch calculations are made using the signal given to the doubling check procedure.

This procedure begins with a fractional pitch refinement around P. This produces tentative values for P_c and $r(P_c)$. Next, the largest value of k is found for which $r(P_c/k) > D_{th} r(P_c)$, where $(P_c/k) \geq 20$ and $k = 8,7,...,2$. $r(P_c/k)$ is calculated in two steps: 1) a fractional pitch refinement around P_c/k, producing P_k; and 2) a double verification, if $P_k < 30$. If such a k is found, then a fractional pitch refinement around P_k is performed, producing new values for P_c and $r(P_c)$.

Finally, if P_c is less than 30 samples, then double verification is performed.

The following pseudo code shows the pitch double check procedure:

```
    inputs: signal; P; Dth
    outputs: Pc, cor_Pc

    Pc, cor_Pc = frac_pitch(signal, P)
    for (k=8; k>=2; k--)
        Pk = Pc/k
        if (Pk >= 20)
            Pk, cor_Pk = frac_pitch(signal, Pk)
            if (Pk < 30) cor_Pk = double_ver(Pk, cor_Pk)
            if (cor_Pk > Dth * cor_Pc)
                Pc, cor_Pc = frac_pitch(signal, Pk)
                break
            endif
        endif
    endfor
```

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```
if (Pc < 30) cor_Pc = double_ver(Pc, cor_Pc)
```

For inputs P and $r(P)$, the double verification procedure returns the smaller of $r(P)$ and $r(2P)$, where $r(2P)$ is determined by the fractional pitch procedure around $2P$. The use of double verification in the double check procedure provides robustness against spurious short pitch values.

A5.2.11 Gain calculation. The input speech signal gain is measured twice per frame using a pitch-adaptive window length. This length is identical for both gain measurements and is determined as follows. When $Vbp_1 > 0.6$, the window length is the shortest multiple of P_2 which is longer than 120 samples. If this length exceeds 320 samples, it is divided by 2. When $Vbp_1 \le 0.6$, the window length is 120 samples. The gain calculation for the first window produces G_1 and is centered 90 samples before the last sample in the current frame. The calculation for the second window produces G_2 and is centered on the last sample in the current frame. The gain is the RMS value, measured in dB, of the signal in the window, s_n:

$$G_i = 10\log_{10}\left(0.01 + \frac{1}{L}\sum_{n=1}^{L} s_n^2\right), \textbf{EQUATION A-6},$$

where L is the window length. The 0.01 term prevents the log argument from going too close to zero. If a gain measurement is less than 0.0, it is clamped to 0.0. The gain measurement assumes that the input signal range is -32768 to 32767 (see 5.2).

A5.2.12 Average pitch update. The long-term average pitch, P_{avg}, is updated with a simple smoothing procedure. If $r(P_3) > 0.8$ > 0.8 and $G_2 > 30\text{dB}$, then P_3 is placed into a buffer containing the three most recent strong pitch values, p_i, $i = 1,2,3$. Otherwise, all three pitch values in the buffer are moved toward a default pitch, $P_{default} = 50$ samples, according to:

$$p_i = 0.95p_i + 0.05P_{default}, i = 1,2,3, \textbf{EQUATION A-7}.$$

The average pitch is then updated as the median of the three values in the buffer. P_{avg} is used in the final pitch calculation (see A5.2.9).

A5.2.13 Quantization of prediction coefficients. First, the linear prediction coefficients a_i, $i = 1,2,...,10$, are converted into LSFs. Next, a process which forces the LSF components to be in ascending order with a minimum separation of 50 Hz is performed. This process begins by checking all adjacent pairs of the LSF components and swapping any pair not in ascending order. This step is repeated as many as ten times, if necessary. The minimum separation criterion is then applied by correcting each pair, f_i and f_{i+1}, for which $d = f_{i+1} - f_i$ is less than 50 Hz, Δ_{min}, as shown in the following pseudo code. The LSF components and frequency-related constants are in Hertz; scaling in other implementations may differ. The minimum separation process is repeated ten times.

```
Dmin = 50
for (I=1; I<10; I++)
    d = f[I+1] - f[I]
```

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```
    if (d < dmin)
       s1 = s2 = (dmin-d)/2
       if (I == 1 and f[I] < dmin) s1 = f[I]/2
       else if (I > 1)
          tmp = f[I] - f[I-1]
          if      (tmp < dmin)   s1 = 0
          else if (tmp < 2*dmin) s1 = (tmp-dmin)/2
       endif
       if (I == 9 and f[I+1] > 4000-dmin) s2 = (4000-f[I+1])/2
       else if (I < 9)
          tmp = f[I+2] - f[I+1]
          if      (tmp < dmin)   s2 = 0
          else if (tmp < 2*dmin) s2 = (tmp-dmin)/2
       endif
       f[I+1] = f[I+1] + s2
    endif
 endfor
```

The resulting LSF vector, f, is then quantized using a MSVQ. The MSVQ codebook consists of four stages of 128, 64, 64, and 64 levels respectively. The quantized vector, $\hat{f}$, is the sum of the vectors selected by the search process, with one vector selected from each stage. The MSVQ search finds the codebook vector which minimizes the square of the weighted Euclidean distance, d^2 , between the unquantized and quantized LSF vectors:

$$d^2\left(f,\hat{f}\right)=\sum_{i=1}^{10} w_i\left(f_i-\hat{f}_i\right)^2, \text{ where } w_i = \begin{cases} P(f_i)^{0.3}, 1 \le i \le 8 \\ 0.64P(f_i)^{0.3}, i = 9 \\ 0.16P(f_i)^{0.3}, i = 10 \end{cases} \text{, } \textbf{EQUATION A-8},$$

f_i is the I^{th} component of the unquantized LSF vector, and $P(f_i)$ is the inverse prediction filter power spectrum evaluated at frequency f_i. The search procedure is an M-best approximation to a full search, in which the M=8 best code vectors from each stage are saved for use with the next stage. The process to ensure ascending order and minimum separation (described in the first part of this section) is then applied to the quantized LSF vector. The resulting vector is used in the Fourier magnitude calculation (see A5.2.17).

A5.2.14 Pitch quantization. The final pitch value, P_3 , is quantized on a logarithmic scale with a 99-level uniform quantizer ranging from 20 to 160 samples. These pitch values are then mapped to a 7-bit codeword using a look-up table, as shown in section 5.3.1. The all-zero codeword represents the unvoiced state, and is sent if $Vbp_1 \le 0.6$. All 28 codewords with Hamming weight of 1 or 2 are reserved for error protection. The uniform quantizer details are described in 5.3.7.

A5.2.15 Gain quantization. The two gain values are quantized as follows. G_2 is quantized with a 5-bit uniform quantizer ranging from 10 to 77 dB. G_1 is quantized to 3 bits using the following adaptive algorithm. If G_2 for the current frame is within 5 dB of G_2 for the previous frame, and G_1 is within 3 dB of the average of the G_2 values for the current and previous frames, then the frame is steady-state and a special code (all zero) is sent to indicate that the decoder should set G_1 to the mean of the G_2 values for the current and previous frames. Otherwise, the frame represents a transition and G_1 is quantized with a 7-level uniform quantizer ranging from 6 dB below the minimum of the G_2 values for the current and previous frames to 6 dB above the maximum of those G_2 values. The quantizer range is clamped to 10 and 77 dB. The uniform quantizer details are described in 5.3.7. Pseudo code for the adaptive quantization of G_1 is shown below.

```
If (|G2 - G2p| < 5.0 and |G1 - 0.5 *(G2 + G2p)| < 3.0)
   quantizer_index = 0
else
   gain_max = max(G2p, G2) + 6.0
   gain_min = min(G2p, G2) - 6.0
   if (gain_min < 10.0) gain_min = 10.0
   if (gain_max > 77.0) gain_max = 77.0
   quantizer_index values 1 to 7 are determined by quantizing G1 with a 7-level,
   uniform quantizer ranging from gain_min to gain_max
endif
```

A5.2.16 Bandpass voicing quantization. When $Vbp_1 \le 0.6$ (unvoiced), the remaining voicing strengths, $Vbp_i, i = 2,3,4,5$, are quantized to 0. When $Vbp_1 > 0.6$, the remaining voicing strengths are quantized to 1 if their value exceeds 0.6, and quantized to 0 otherwise. There is one exception. If the quantized values of $Vbp_i, i = 2,3,4,5$ are 0001, respectively, then Vbp_5 is quantized to 0.

A5.2.17 Fourier magnitude calculation and quantization. This analysis measures the Fourier magnitudes of the first 10 pitch harmonics of the prediction residual generated by the quantized prediction coefficients. It uses a 512-point Fast Fourier Transform (FFT) of a 200 sample window centered at the end of the frame. First, a set of quantized predictor coefficients is calculated from the quantized LSF vector (see A5.2.13). Then the residual window is generated using the quantized prediction coefficients. Next, a 200 sample Hamming window is applied, the signal is zero-padded to 512 points, and the complex FFT is performed. Finally, the complex FFT output is transformed into magnitudes, and the harmonics are found with a spectral peak-picking algorithm.

The peak-picker finds the maximum within a width of $512/\hat{P}_3$ frequency samples centered around the initial estimate for each pitch harmonic, where $\hat{P}_3$ is the quantized pitch. This width is truncated to an integer. The initial estimate for the location of the Ith harmonic is $512i/\hat{P}_3$. The number of harmonic magnitudes searched for is limited to the smaller of 10 or $\hat{P}_3/4$. These magnitudes are then normalized to have an RMS value of 1.0. If fewer than 10 harmonics are found, the remaining magnitudes are set to 1.0.

The 10 magnitudes are quantized with an 8-bit vector quantizer. The codebook is searched using a perceptually weighted Euclidean distance, with fixed weights that emphasize low frequencies over higher frequencies. The weights are given by:

$$w_i = \left[\frac{117}{25 + 75\left(1 + 1.4\left(\frac{f_i}{1000}\right)^2\right)^{0.69}} \right]^2, i = 1,2,...,10,\ \textbf{EQUATION A-9},$$

where $f_i = 8000i / 60$ is the frequency in Hz corresponding to the I^{th}harmonic for a default pitch period of 60 samples. The weights are applied to the squared difference between the input Fourier magnitudes and the codebook values.

A5.2.18 Error protection and bit packing. Table II in 5.5.2 shows the bit allocation for the MELP coder. To improve performance in channel errors, the unused coder parameters for the unvoiced mode are replaced with forward error correction. Three Hamming (7,4) codes and one Hamming (8,4) code are used. The (7,4) code corrects single bit-errors, while the (8,4) code in addition detects double bit-errors. The (8,4) code is applied to the 4 most significant bits (MSBs) of the first MSVQ index, and the 4 parity bits are written over the bandpass voicing. The remaining 3 bits of the first MSVQ index along with a reserved bit (set to zero), are covered by a (7,4) code with the resulting 3 parity bits written to the MSBs of the Fourier series VQ index. The 4 MSBs of the G_2 codeword are protected with 3 parity bits which are written to the next 3 bits of the Fourier magnitudes. Finally, the LSB of the second gain index and the 3 bit G_1 codeword are protected with 3 parity bits written to the 2 LSBs of the Fourier magnitudes and the aperiodic flag.

The bit transmission order is given in 5.5.3.

A.5.3 Decoder. The channel data is decoded by performing the following steps in the order given.

A5.3.1 Bit unpacking and error correction. The received bits are unpacked from the channel and assembled into the parameter codewords. Parameter decoding is different for voiced and unvoiced modes. The pitch is decoded first, since it contains the mode information. If the pitch code is all-zero or has only one bit set, then the unvoiced mode is used. If two bits are set, a frame erasure is indicated. Otherwise, the pitch value is decoded and the voiced mode is used.

In the unvoiced mode, the (8,4) Hamming code is decoded to correct single bit errors and detect double errors. If an uncorrectable error is detected, a frame erasure is indicated. Otherwise, the (7,4) Hamming codes are decoded, correcting single errors but without double error detection.

If any erasure is detected in the current frame, by the Hamming code, by the pitch code, or directly signaled from the channel, then a frame repeat mechanism is implemented. All of the parameters for the current frame are replaced with the parameters from the previous frame. In addition, the first gain term is set equal to the second gain term so that no gain transitions are allowed.

If an erasure is not indicated, the remaining parameters are decoded. The LSFs are checked for ascending order and minimum separation as described in A5.2.13. In the unvoiced mode, default parameter values are used for the pitch, jitter, bandpass voicing, and Fourier magnitudes. The pitch value is set to 50 samples, the jitter is set to

25%, all of the bandpass voicing strengths are set to 0, and the Fourier magnitudes are set to 1. In the voiced mode, Vbp_1 is set to 1; jitter is set to 25% if the aperiodic flag is a 1; otherwise jitter is set to 0%. The bandpass voicing strength for the upper four bands is set to 1 if the corresponding bit is a 1; otherwise the voicing strength is set to 0. There is one exception. If 0001 is received for $Vbp_i, i = 2,3,4,5$, respectively, then Vbp_5 is set to 0.

When the special all-zero code for the first gain parameter, G_1, is received, some errors in the second gain parameter, G_2, can be detected and corrected. This correction process provides improved performance in channel errors. The decoding for the two gain parameters is shown in the following pseudo code.

```
Inputs: G1_index, G2_index
outputs: G1, G2
internal: G2p, G2p_error

G2 = decode(G2_index)            32 levels; range: 10 to 77 dB
if (G1_index == 0)               special G1 code: use mean of G2 and G2p
   if (|G2 - G2p| > 5)           G2_index probably in error
      if (G2p_error == 0)        G2p is correct
         G2 = G2p                replace the erroneous G2 with past value
      endif
      G2p_error = 1
   else  G2_index probably correct
      G2p_error = 0
   endif
   G1 = 0.5 * (G2 + G2p)         mean of G2 and G2p
else
   G1 = decode(G1_index)         7 levels; range: min(G2,G2p)-6 to max(G2,G2p)+6
   G2p_error = 0                 (above range is clamped to 10 to 77 dB)
endif
G2p = G2                         save for use as past value
```

A5.3.2 Noise attenuation. For quiet input signals, a small amount of gain attenuation is applied to both decoded gain parameters using a power subtraction rule. This attenuation is a simplified, frequency invariant case of the Smoothed Spectral Subtraction noise suppression method.

Before determining the attenuation for the first gain term, G_1, a background noise estimate, G_n, is updated as follows. If $G_1 > G_n + C_{up}$ then $G_n = G_n + C_{up}$. If $G_1 < G_n - C_{down}$ then $G_n = G_n - C_{down}$. Otherwise, $G_n = G_1$. $C_{up} = 0.0337435$ and $C_{down} = 0.135418$, so that the noise estimator moves up by 3 dB per second and down by 12 dB per second for the gain update rate of 88.9 updates per second. The noise estimate is clamped between 10 and 80. Noise estimation is disabled for repeated frames to prevent repeated attenuation. The background noise estimate is also used in the adaptive spectral enhancement calculation (see A5.3.5).

Gain G_1 is then modified by subtracting a (positive) correction term, G_{att}, given in dB by

$$G_{att} = -10\log_{10}\left(1 - 10^{0.1[G_n + 3 - G_1]}\right), \textbf{EQUATION A-10},$$

where G_n is the background noise estimate (in dB), and G_1 is the first gain term (in dB). The correction is clamped to a maximum value of 6 dB to avoid fluctuations and signal distortion. To ensure that the attenuation is applied only to quiet signals, the G_n value as used in equation A-10 is clamped at an upper limit of 20 dB.

The noise estimation and gain modification steps are then repeated for the second gain term, G_2. Noise estimation and gain attenuation are disabled for repeated frames.

A5.3.3 Parameter interpolation. All MELP synthesis parameters are interpolated pitch-synchronously for each synthesized pitch period. The interpolated parameters are the gain (in dB), LSFs, pitch, jitter, Fourier magnitudes, pulse and noise coefficients for mixed excitation, and spectral tilt coefficient for the adaptive spectral enhancement filter. Gain is linearly interpolated between the second gain of the prior frame, G_{2p}, and the first gain of the current frame, G_1, if the starting point, $t_0, t_0 = 0,1,...,179$, of the new pitch period is less than 90; otherwise, gain is interpolated between G_1 and G_2. Normally, the other parameters are linearly interpolated between the past and current frame values. The interpolation factor, int, for these parameters is based on the starting point of the new pitch period:

$$\text{int} = t_0 / 180 \text{, } \textbf{EQUATION A-11}.$$

There are two exceptions to this interpolation procedure. First, if there is an onset with a high pitch frequency, pitch interpolation is disabled and the new pitch is immediately used. This condition is met when G_1 is more than 6 dB greater than G_{2p} and the current frame's pitch period is less than half the prior frame's pitch period. The second exception also involves a gain onset. If G_2 differs from G_{2p} by more than 6 dB, then the LSF's, spectral tilt, and pitch are interpolated using the interpolated gain trajectory as a basis, since the gain is transmitted twice per frame and has a more accurate interpolation path. In this case, the interpolation factor is given by

$$\text{int} = \frac{G_{\text{int}} - G_{2p}}{G_2 - G_{2p}} \text{,} \textbf{EQUATION A-12},$$

where G_{int} is the interpolated gain. This interpolation factor is then clamped between 0 and 1.

A5.3.4 Mixed excitation generation. The mixed excitation is generated as the sum of the filtered pulse and noise excitations. The pulse excitation, $e_p(n), n = 0,1,..., T-1$, is computed using an inverse Discrete Fourier Transform of one pitch period in length:

$$e_p(n) = \frac{1}{T} \sum_{k=0}^{T-1} M(k)\ e^{j2\pi nk/T} \text{, } \textbf{EQUATION A-13}.$$

The pitch period, T, is the interpolated pitch value plus the jitter times the pitch, where the jitter is the interpolated jitter strength times the output of a uniform random number generator between -1 and 1. This pitch period is rounded to the nearest integer and clamped between 20 and 160. All of the phases for the pulse excitation are set to zero, hence $M(k)$ is real. Since $e_p(n)$ is real, the magnitudes obey:

$$M(T-k) = M(k), k = 1,2,\ldots, L$$ **EQUATION A-14**,

where $L = T/2$ if T is even, and $L = (T-1)/2$, if T is odd. The DC term, $M(0)$, is set to 0. Magnitude terms $M(k), k = 1,2,\ldots,10$, are set to the interpolated values of the Fourier magnitudes, and any magnitudes not otherwise specified are set to 1. To prevent rapid changes at the start of the pitch period, the pulse excitation is circularly shifted by ten samples of delay so the main excitation pulse occurs at the tenth sample of the period. The pulse is then multiplied by the square root of the pitch to give a unity RMS signal, and then multiplied by 1000 to give a nominal signal level.

The noise is generated by a uniform random number generator with an RMS value of 1000, and range of -1732 to 1732.

The pulse and noise excitation signals are then filtered and summed to form the mixed excitation. The pulse filter for the current frame is given by the sum of all the bandpass filter coefficients for the voiced frequency bands, while the noise filter is given by the sum of the bandpass filter coefficients for the unvoiced bands. These filter coefficients are interpolated pitch synchronously. The bandpass filter coefficients for each of the five bands are given in table A-I.

TABLE A-I. Filter coefficients for bandpass filter.

0-500 Hz	500-1000 Hz	1000-2000 Hz	2000-3000 Hz	3000-4000Hz
-0.00302890	-0.00249420	-0.00231491	0.00231491	0.00554149
-0.00701117	-0.00282091	0.00990113	0.00990113	-0.00981750
-0.01130619	0.00257679	0.02086129	-0.02086129	0.00856805
-0.01494082	0.01451271	-0.00000000	0.00000000	-0.00000000
-0.01672586	0.02868120	-0.03086123	0.03086123	-0.01267517
-0.01544189	0.03621179	-0.02180695	-0.02180695	0.02162277
-0.01006619	0.02784469	0.00769333	-0.00769333	-0.01841647
0.00000000	0.00000000	-0.00000000	-0.00000000	0.00000000
0.01474923	-0.04079870	-0.01127245	0.01127245	0.02698425
0.03347158	-0.07849207	0.04726837	0.04726837	-0.04686914
0.05477206	-0.09392213	0.10106105	-0.10106105	0.04150730
0.07670890	-0.07451087	-0.00000000	0.00000000	-0.00000000
0.09703726	-0.02211575	-0.17904543	0.17904543	-0.07353666
0.11352143	0.04567473	-0.16031428	-0.16031428	0.15896026
0.12426379	0.10232715	0.09497157	-0.09497157	-0.22734513
0.12799355	0.12432599	0.25562154	0.25562154	0.25346255

TABLE A-I. Filter coefficients for bandpass filter - Continued.				
0-500 Hz	**500-1000 Hz**	**1000-2000 Hz**	**2000-3000 Hz**	**3000-4000Hz**
0.12426379	0.10232715	0.09497157	-0.09497157	-0.22734513
0.11352143	0.04567473	-0.16031428	-0.16031428	0.15896026
0.09703726	-0.02211575	-0.17904543	0.17904543	-0.07353666
0.07670890	-0.07451087	-0.00000000	0.00000000	-0.00000000
0.05477206	-0.09392213	0.10106105	-0.10106105	0.04150730
0.03347158	-0.07849207	0.04726837	0.04726837	-0.04686914
0.01474923	-0.04079870	-0.01127245	0.01127245	0.02698425
0.00000000	-0.00000000	-0.00000000	-0.00000000	0.00000000
-0.01006619	0.02784469	0.00769333	-0.00769333	-0.01841647
-0.01544189	0.03621179	-0.02180695	-0.02180695	0.02162277
-0.01672586	0.02868120	-0.03086123	0.03086123	-0.01267517
-0.01494082	0.01451271	-0.00000000	0.00000000	-0.00000000
-0.01130619	0.00257679	0.02086129	-0.02086129	0.00856805
-0.00701117	-0.00282091	0.00990113	0.00990113	-0.00981750
-0.00302890	-0.00249420	-0.00231491	0.00231491	0.00554149

A5.3.5 Adaptive spectral enhancement. The adaptive spectral enhancement filter is applied to the mixed excitation signal. This filter is a tenth order pole/zero filter, with an additional first-order tilt compensation. Its coefficients are generated by bandwidth expansion of the linear prediction filter transfer function, $A(z)$, corresponding to the interpolated LSFs. The transfer function of the enhancement filter, $H_{ase}(z)$, is given by:

$$H_{ase}(z) = \frac{A(\alpha z^{-1})}{A(\beta z^{-1})} * (1 + \mu z^{-1}), \text{ where } \begin{matrix} \alpha = 0.5p \\ \beta = 0.8p \end{matrix}, \textbf{EQUATION A-15},$$

and tilt the coefficient μ is first calculated as $\max(0.5k_1, 0)$, then interpolated, then multiplied by p, the signal probability. The first reflection coefficient, k_1, is calculated from the decoded LSFs. By the MELP predictor coefficient sign convention, k_1 is usually negative for voiced spectra. The signal probability p is estimated by comparing the current interpolated gain, G_{int}, to the background noise estimate G_n using the formula:

$$p = \frac{G_{int} - G_n - 12}{18}, \textbf{EQUATION A-16}.$$

This signal probability is clamped between 0 and 1.

A5.3.6 Linear prediction synthesis. The synthesis uses a direct form filter, with the coefficients corresponding to the interpolated LSFs.

A5.3.7 Gain adjustment. Since the excitation is generated at an arbitrary level, the speech gain must be introduced to the synthesized speech. The correct scaling factor, S_{gain}, is computed for each synthesized pitch period of length T by dividing the desired RMS value (G_{int} must be converted from dB) by the RMS value of the unscaled synthetic speech signal $\hat{s}_n$:

$$S_{gain} = \frac{10^{G_{int}/20}}{\sqrt{\frac{1}{T}\sum_{n=1}^{T}\hat{s}_n^2}}$$, **EQUATION A-19**.

To prevent discontinuities in the synthesized speech, this scale factor is linearly interpolated between the previous and current values for the first ten samples of the pitch period.

A5.3.8 Pulse dispersion. The pulse dispersion filter is a 65th order FIR filter derived from a spectrally-flattened triangle pulse. The coefficients are listed in table A-II.

TABLE A-II. Filter coefficients for the pulse dispersion filter.

Samples 1-13	Samples 14-26	Samples 27-39	Samples 40-52	Samples 53-65
-0.17304259	0.24325127	0.07343483	0.02968464	0.00019707
-0.01405709	-0.01767043	-0.00518645	-0.01247640	-0.02825247
0.01224406	-0.00018612	0.01298488	0.01854666	0.01720989
0.11364226	0.05869485	0.02928440	0.00076184	-0.06004292
0.00198199	-0.00327456	-0.01989405	-0.07749640	-0.07076744
0.00000658	0.00607395	0.01216758	0.01244697	0.00914347
0.04529633	0.02753924	0.01180979	-0.02721777	0.06082730
-0.00092027	-0.03351673	-0.38924775	0.07266098	0.01805528
-0.00103078	0.00602189	0.00720325	0.00472008	-0.00318634
0.02552787	0.01436539	-0.01154561	0.03526439	0.03444110
-0.06339257	0.82854582	0.08426287	0.02674603	0.00026302
-0.00122031	0.00033165	-0.00355720	-0.00744038	-0.01053809
0.01412525	-0.00360180	0.02151233	0.02582623	0.02165922

A5.3.9 Synthesis loop control. After processing each pitch period, the decoder updates t_0 by adding T, the number of samples in the period just synthesized. If $t_0 < 180$, synthesis for the current frame continues from the parameter interpolation step (see A5.3.3). Otherwise, the decoder buffers the remainder of the current period which extends beyond the end of the current frame and subtracts 180 from t_0 to produce its initial value next frame.

APPENDIX B

PERFORMANCE VERIFICATION

B.1 SCOPE

B.1.1 Scope. This appendix is a mandatory part of this standard. The information contained herein is intended for compliance. All new implementations of the MELP coder must be tested to verify that their performance meets or exceeds that of the MELP reference coder. This appendix provides guidelines for verifying the performance of a MELP implementation. Two methods of verification are presented.

B.2 APPLICABLE DOCUMENTS

B.2.1 Government documents. Not applicable.

B.2.2 Other publications. The following documents form a part of this appendix to the extent specified.

ANSI Standard

S3.2-1989	American National Standard Method for Measuring the Intelligibility of Speech over Communications Systems

(Applications for copies should be addressed to ANSI Customer Service, 11 West 42nd Street, New York, New York 10036, USA)

INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS (IEEE)

"IEEE Recommended Practice for Speech Quality Measurements" by IEEE Subcommittee on Subjective Measurements, Transactions on Audio and Electroacoustics, Vol. 17, 1969, pp. 227-246

(Applications for copies should be addressed to IEEE Customer Service, 445 Hoes Lane, P.O. Box 1331 Piscataway, New Jersey 08855-1331, USA)

B.2.3 Order of precedence. In the event of a conflict between the text of this standard and the references stated herein, the text of this standard should take precedence.

B.3 DEFINITIONS

B.3.1 Terms. Terms used in this appendix are defined in section 3.1 of the standard or as follows.

B3.1.1 A/B test. An A/B test is a direct paired forced choice comparison test that is used to assess the quality of one voice coder against another voice coder.

B.3.2 Acronyms used in this appendix. Acronyms used in this section are either defined in 3.2 of the standard or as follows.

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ANSI - American National Standards Institute

DRT - Diagnostic Rhyme Test

PCM - Pulse Code Modulation

B.4 GENERAL REQUIREMENTS

B.4.1 General. New implementations of MELP must be verified to assure that their performance meets or exceeds the performance of the MELP reference coder. A new implementation must also meet the same performance standards when interoperating with the MELP reference coder. Testing is accomplished through formal evaluation of intelligibility and quality or by showing bit equivalence between the new implementation and a verified MELP implementation. Both verification methods evaluate an implementation over an extensive set of conditions.

B.5 DETAILED REQUIREMENTS

B.5.1 Formal evaluation. The intelligibility of a new implementation is evaluated using the DRT. DRT performance thresholds have been set and are discussed later in this section. Quality is evaluated using a direct paired forced choice comparison test, i.e., an A/B test. Performance thresholds for the quality tests have also been set and are based on the percent preference for the new implementation over the MELP reference coder. The Federal Standard CELP coder is also included in the quality test to broaden the context of the test and to include a known difference from MELP. Table B-I summarizes the coder configurations which are evaluated for intelligibility and quality. In table B-I, the "Implementation →MELP Reference" and "MELP Reference → Implementation" cases are "cross-coder" configurations which test interoperability. Table B-II shows the intelligibility and quality test conditions. Six talkers (3 male, 3 female) are used for each condition.

TABLE B-I. Tested coder configurations.

Intelligibility (Encoder → Decoder)	**Quality (Encoder → Decoder)**
Implementation →Implementation	Implementation → Implementation
Implementation → MELP Reference	Implementation → MELP Reference
MELP Reference → Implementation	MELP Reference → Implementation
	MELP Reference → MELP Reference
	CELP → CELP

APPENDIX B

TABLE B-II. Intelligibility and qualilty test conditions.

Intelligibility Condition (microphone)	Quality Condition (microphone)
Quiet (Dynamic)	Quiet (Dynamic)
Quiet (H250)	Quiet (H250)
Office (STU-III)	Office (STU-III)
E3A AWACS (R215)	E3A AWACS (R215)
HMMWV (H250)	HMMWV (H250)
MCE Field Shelter (M87)	MCE Field Shelter (M87)
Car (STU-III cellular)	Car (STU-III cellular)
0.5% Block Error Rate in Quiet (Dynamic)	0.5% Block Error Rate in Quiet (Dynamic)
1.0% Bit Error Rate in Quiet (Dynamic)	1.0% Bit Error Rate in Quiet (Dynamic)
CVSD → Coder in Quiet (Dynamic)	CVSD → Coder in Quiet (Dynamic)
CVSD → Coder → CVSD in Quiet (Dynamic)	CVSD → Coder → CVSD in Quiet (Dynamic)
M2 Bradley (M138)	
CH47 helicopter (M87)	
F-15 jet (M101)	
P3C Orion plane (EV985)	

B5.1.1 Intelligibility tests. The DRT will be performed in accordance with ANSI standard S3.2-1989 and will be scored with eight listeners. The combined talker score determined by the test lab must meet or exceed the corresponding threshold score for each condition and for the weighted combination of all conditions. Table B-III shows the weight and threshold score for each condition. The implementation's combined score is calculated by multiplying its individual score for each condition by the corresponding weight given in table B-III. The results are then summed to produce the combined result. This process is used for each of the three coder configurations evaluated for intelligibility. The threshold score for each condition is based on a one-tail 99.5% confidence interval; the combined threshold score is based on a one-tail 99% confidence interval.

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TABLE B-III. Weights and thresholds for intelligibility conditions.		
Intelligibility condition (microphone)	**Weight**	**Threshold score**
Quiet (Dynamic)	0.100	90.80
Quiet (H250)	0.100	88.77
Office (STU-III)	0.0667	89.34
E3A AWACS (R215)	0.0667	85.10
HMMWV (H250)	0.0667	61.88
MCE Field Shelter (M87)	0.0667	87.28
Car (STU-III cellular)	0.0667	82.48
M2 Bradley (M138)	0.0667	61.33
CH47 helicopter (M87)	0.0667	63.27
F-15 jet (M101)	0.0667	75.06
P3C Orion plane (EV985)	0.0667	82.98
0.5% Block Error Rate in Quiet (Dynamic)	0.050	89.58
1.0% Bit Error Rate in Quiet (Dynamic)	0.050	87.47
CVSD → Coder in Quiet (Dynamic)	0.050	84.07
CVSD → Coder → CVSD in Quiet (Dynamic)	0.050	81.33
Combined (weighted)	1.000	82.634

B5.1.2 Quality tests. The quality of the three coder configurations involving the new implementation (see table B-I) is compared with the quality of the MELP reference coder using a direct paired forced choice comparison (A/B) test. Quality is measured in each condition by the percent preference taken over all talkers and listeners. For each coder configuration involving the new implementation, the percent preferred must meet or exceed the threshold for each condition and for the weighted combination of all conditions.

The threshold for individual conditions is 45.84%, i.e., each coder configuration involving the new implementation must have a preference percentage of 45.84% or more in each condition. This threshold is equivalent to saying that the new implementation must be selected at least 440 times out of the 960 comparisons between the new implementation and the reference in each condition. The threshold is based on a one-tail 99.5% confidence interval.

The combined percent preferred is calculated for each of the three coder configurations by summing the weighted individual condition percentages using the weights listed in table B-IV. The combined threshold percentage is 48.71%, i.e., each of the three coder configurations involving the new implementation must have a combined preference percentage of 48.71% or more. The combined threshold is based on a one-tail 99% confidence interval.

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TABLE B-IV. Weights for quality conditions.

Quality condition (microphone)	Weight
Quiet (Dynamic)	0.245
Quiet (H250)	0.105
Office (STU-III)	0.070
E3A AWACS (R215)	0.070
HMMWV (H250)	0.070
MCE Field Shelter (M87)	0.070
Car (STU-III cellular)	0.070
0.5% Block Error Rate in Quiet (Dynamic)	0.075
1.0% Bit Error Rate in Quiet (Dynamic)	0.075
CVSD → Coder in Quiet (Dynamic)	0.075
CVSD → Coder → CVSD in Quiet (Dynamic)	0.075

B.5.2 Bit equivalence. A lower cost alternative for implementation verification is accomplished by demonstrating that the new implementation is bit equivalent to a verified MELP implementation. Bit equivalent means that given the same input, the new implementation's encoder produces the same bitstream as produced by the encoder of the verified MELP implementation. Also given the same bitstream, the new implementation's decoder produces the same 16 bit PCM samples as produced by the decoder of the verified MELP implementation. This equivalence must be shown for all intelligibility material and quality material used in the formal evaluation.

CONCLUDING MATERIAL

Custodians:

Army – CR
Navy – EC
Air Force – 02
NSA – NS

Review Activities:

Army – AM
Navy – MC, NC, TD
Air Force – 11, 13, 19, 93
DISA – DC1

Preparing Activity:

NSA – NS

(Project TCSS-0044)

STANDARDIZATION DOCUMENT IMPROVEMENT PROPOSAL

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1. The preparing activity must complete blocks 1, 2, 3, and 8. In block 1, both the document number and revision letter should be given.

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I RECOMMEND A CHANGE:	1. DOCUMENT NUMBER	2. DOCUMENT DATE (YYYYMMDD)
	MIL-STD-3005	19991220

3. DOCUMENT TITLE ANALOG-TO-DIGITAL CONVERSION OF VOICE BY 2,4000 BIT/SECOND MIXED EXCITATION LINEAR PREDICTION (MELP)

5. REASON FOR RECOMMENDATION

6. SUBMITTER

a. NAME *(Last, First, Middle Initial)*	b. ORGANIZATION	
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