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FIPS PUB 137, Analog to Digital Conversion of Voice by 2,400 Bit/Second Linear Predictive Coding.

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CHANGE ITEM(S)

Specific Change

Section 1.3, Application which requires the capability for LPC-10 in all Government 2,400 bit/s synchronous digitized voice equipment is changed to make the use of and capability for LPC-10 operation **non-mandatory.**

This change will allow for the use of newer 2,400 bit/s digitized voice techniques, including Mixed Excitation Linear Prediction (MELP), that has recently been developed and will soon be standardized.

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Federal Standard 1015 has been redesignated as Federal Information Processing Standards Publication (FIPS PUB) 137. Issued by the National Institute of Standards and Technology pursuant to Section 111(d) of the Federal Property and Administrative Services Act of 1949 as amended by the Computer Security Act of 1987, Public Law 100-235

FEDERAL STANDARD 1015

ANALOG TO DIGITAL CONVERSION OF VOICE BY 2,400 BIT/SECOND LINEAR PREDICTIVE CODING

Prepared By:
National Communications System
Office Of Technology & Standards

Published By:
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FEDERAL STANDARD

TELECOMMUNICATIONS: ANALOG TO DIGITAL CONVERSION OF VOICE BY 2,400 BIT/SECOND LINEAR PREDICTIVE CODING

This standard is issued by the General Service Administration pursuant to the Federal Property and Administrative Services Act of 1949, as amended.

1. Scope

1.1 Description. This standard specifies interoperability requirements relating to the conversion of analog voice to 2,400 bit/s digitized voice by Linear Predictive Coding with 10 reflection coefficients (LPC-10), and reconversion back to analog voice.

1.2 Objective. The primary objective of this standard is to facilitate the interoperability of Government communication facilities and systems that employ 2,400 bit/s digitized voice.

1.3 Application. This standard applies to all synchronous (i.e. not packetized) 2,400 bit/s digitized voice telecommunications equipment procured or leased by Federal departments and agencies. While additional analog-to-digital conversion techniques and data rates may be used, all Government synchronous 2,400 bit/s digitized voice equipment shall be capable of LPC-10 operation in conformance with this standard.

2. Related Standards

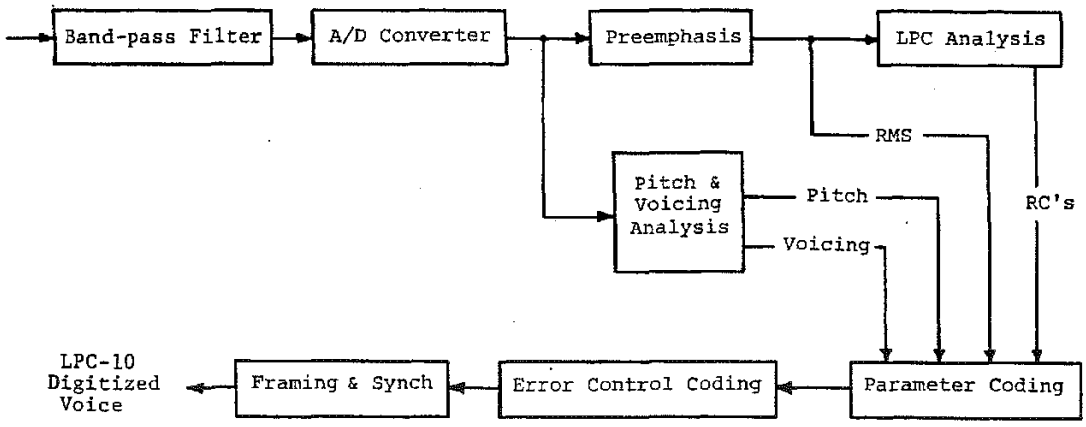
a. Military Standard 188-113: COMMON LONG HAUL/TACTICAL STANDARDS FOR ANALOG/DIGITAL CONVERSION TECHNIQUES. (Copies of this standard are available from the Naval Publications and Forms Center, 5801 Tabor Avenue, Philadelphia, PA 19120).

b. North Atlantic Treaty Organization (NATO) Standardization Agreement (STANAG) 4198: PARAMETERS AND CODING CHARACTERISTICS THAT MUST BE COMMON TO ASSURE INTEROPERABILITY OF 2400 BPS LINEAR PREDICTIVE ENCODED DIGITAL SPEECH (Controlled Distribution). (Copies of this standard are available from the Naval Publications and Forms Center, 5801 Tabor Avenue, Philadelphia, PA 19120).

3. Requirements

3.1 Typical Block Diagrams

3.1.1 Transmitter. The block diagram of a typical Linear Predictive Coding (LPC) transmitter is shown below.



As shown in the diagram above, speech is band-pass filtered prior to analog-to-digital (A/D) conversion. After A/D conversion and preemphasis, Linear Predictive Coding (LPC) analysis is accomplished to determine reflection coefficients (RCs). Also, root-mean-square (RMS) amplitude is calculated. Additionally, after A/D conversion, pitch and voicing analysis is accomplished to determine whether to treat the LPC coded frame as voiced or otherwise. If voiced, pitch is determined. If not voiced, a determination is made whether the frame is to be considered as unvoiced or in voicing transition. Next, the RMS amplitude, reflection coefficients, and pitch and voicing are coded; transmission error control coding is added as applicable; a synchronization bit is added; and a 54-bit frame is formed.

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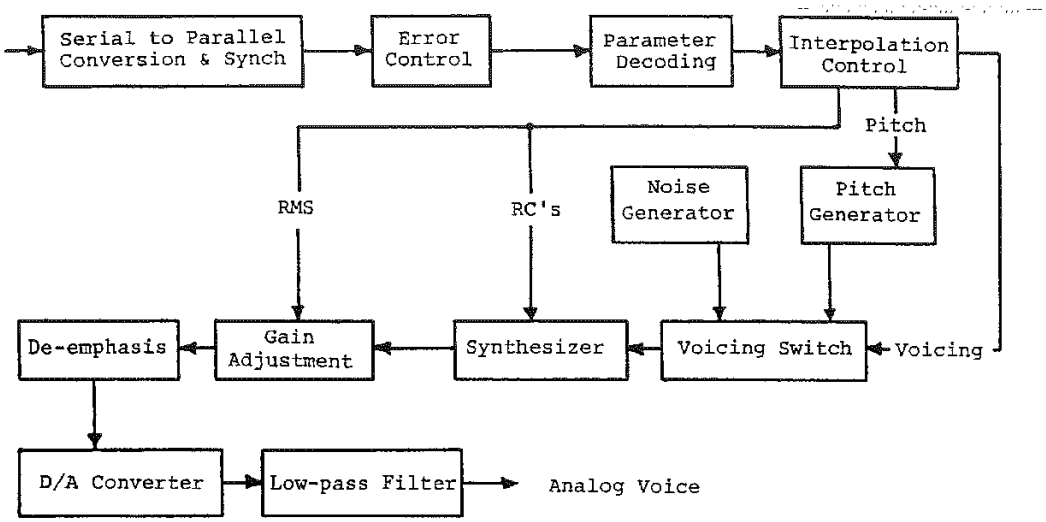
3.1.2 Receiver. The block diagram of a typical Linear Predictive Coding (LPC) receiver is shown below.



As shown in the diagram above, the Linear Predictive Coding (LPC) receiver's digital input is first unframed and error detection and forward error correction are performed, as applicable. Parameter decoding is then performed, along with interpolation and other enhancements, to obtain the proper voicing decision, pitch (for voiced frames), reflection coefficients, and RMS amplitude. Of these parameters, the voicing decision is forwarded to the voicing switch function that chooses the random noise generator (unvoiced) or the pitch generator (voiced) as the synthesizer input. Likewise, the correct pitch is forwarded to the pitch generator (if the frame is determined to be voiced), the reflection coefficients are forwarded to the synthesizer function, and the RMS amplitude is forwarded to the gain adjustment function. Lastly, the output of the gain adjustment function is de-emphasized, converted from digital to analog by a D/A converter, and low-pass filtered. (Note that some filtering is accomplished as a part of the de-emphasis function).

3.2 Input Conditioning

3.2.1 Band-pass Filtering. The LPC transmitter input passband should be essentially flat from 100-3600 Hz. A typically used input filter has 3 dB attenuation points at 100 and 3,600 Hz, less than 1 dB of inband ripple, and attenuations at 4,000 and 4,400 Hz of 23 dB and 46 dB, respectively.

3.2.2 A/D Conversion. Analog-to-digital (A/D) conversion shall use an 8 kHz $\pm$0.1 percent sampling frequency and have a dynamic range of at least 12 bits.

3.2.3 Preemphasis. Preemphasis shall use the first order digital transfer function $1 - 0.9375\ z^{-1}$.

3.3 Transmission Format

3.3.1 Transmission Rate. The transmission rate shall be 2400 bits/s $\pm$.01 percent. Since all frames contain 54 bits, the frame length is 22.5 ms $\pm$.01 percent.

3.3.2 Bit Allocation. The allocation of the 54 bits in an LPC frame shall be as shown in the following table.

	Voiced	Nonvoiced
Pitch & Voicing	7	7
RMS Amplitude	5	5
RC(1)	5	5
RC(2)	5	5
RC(3)	5	5
RC(4)	5	5
RC(5)	4	
RC(6)	4	
RC(7)	4	
RC(8)	4	
RC(9)	3	
RC(10)	2	
Error Control		20
Synchronization	1	1
Unused		1
Total	54	54

Note: RC = Reflection Coefficient
Nonvoiced = Unvoiced or In Voicing Transition

3.3.3 Bit Assignment. The assignment of bits within an LPC frame shall be as shown in the following table.

Bit	Voiced	Nonvoiced	Bit	Voiced	Nonvoiced	Bit	Voiced	Nonvoiced
1	RC(1)-0	RC(1)-0	19	RC(3)-3	RC(3)-3	37	RC(8)-1	R-6*
2	RC(2)-0	RC(2)-0	20	RC(4)-2	RC(4)-2	38	RC(5)-1	RC(1)-6*
3	RC(3)-0	RC(3)-0	21	R-3	R-3	39	RC(6)-1	RC(2)-6*
4	P-0	P-0	22	RC(1)-4	RC(1)-4	40	RC(7)-2	RC(3)-7*
5	R-0	R-0	23	RC(2)-3	RC(2)-3	41	RC(9)-0	RC(4)-6*
6	RC(1)-1	RC(1)-1	24	RC(3)-4	RC(3)-4	42	P-5	P-5
7	RC(2)-1	RC(2)-1	25	RC(4)-3	RC(4)-3	43	RC(5)-2	RC(1)-7*
8	RC(3)-1	RC(3)-1	26	R-4	R-4	44	RC(6)-2	RC(2)-7*
9	P-1	P-1	27	P-3	P-3	45	RC(10)-1	Unused
10	R-1	R-1	28	RC(2)-4	RC(2)-4	46	RC(8)-2	R-7*
11	RC(1)-2	RC(1)-2	29	RC(7)-0	RC(3)-5*	47	P-6	P-6
12	RC(4)-0	RC(4)-0	30	RC(8)-0	R-5*	48	RC(9)-1	RC(4)-7*
13	RC(3)-2	RC(3)-2	31	P-4	P-4	49	RC(5)-3	RC(1)-8*
14	R-2	R-2	32	RC(4)-4	RC(4)-4	50	RC(6)-3	RC(2)-8*
15	P-2	P-2	33	RC(5)-0	RC(1)-5*	51	RC(7)-3	RC(3)-8*
16	RC(4)-1	RC(4)-1	34	RC(6)-0	RC(2)-5*	52	RC(9)-2	RC(4)-8*
17	RC(1)-3	RC(1)-3	35	RC(7)-1	RC(3)-6*	53	RC(8)-3	R-8*
18	RC(2)-2	RC(2)-2	36	RC(10)-0	RC(4)-5*	54	Synch.	Synch.

NOTES:
P = Pitch
R = RMS Amplitude
RC = Reflection Coefficient
* = Error Control Bit
Bit 0 = least significant bit of data
Bit 5 = least significant bit of error control
Order of transmission is from bit 1 to bit 54
Nonvoiced = Unvoiced or In Voicing Transition

3.3.4 Synchronization. The synchronization bit shall alternate between ZERO and ONE from frame to frame.

3.4 Pitch and Voicing

3.4.1 Encoding. Pitch and voicing information shall be coded as a seven bit field. For error protection purposes, unvoiced frames shall be coded as seven ZERO bits and frames in voicing transition shall be coded as seven ONE bits. For voiced frames, one of 60 selected pitch values (51-400 Hz) shall be selected and coded as shown in the following table. Note that the pitch period is the sampling frequency (8,000 Hz) divided by the pitch frequency.

Pitch Freq	Pitch Period	Code	Pitch Freq	Pitch Period	Code	Pitch Freq	Pitch Period	Code	Pitch Freq	Pitch Period	Code
51	156	76	83	96	78	138	58	26	235	34	46
53	152	101	87	92	74	143	56	58	242	33	38
54	148	100	91	88	75	148	54	56	250	32	39
56	144	108	95	84	73	154	52	60	258	31	7
57	140	104	100	80	77	160	50	52	266	30	15
59	136	106	103	78	69	167	48	54	276	29	14
61	132	98	105	76	85	174	46	50	286	28	30
63	128	114	108	74	81	184	44	51	296	27	22
65	124	112	111	72	83	190	42	49	308	26	23
67	120	113	114	70	82	200	40	53	320	25	21
69	116	97	118	68	86	205	39	37	333	24	29
71	112	99	121	66	84	210	38	45	348	23	25
74	108	67	125	64	92	216	37	41	364	22	27
77	104	71	129	62	88	222	36	43	381	21	11
80	100	70	133	60	90	228	35	42	400	20	19

3.4.2 Decoding. The following table shall be used in decoding the seven-bit pitch and voicing field to determine if a frame is unvoiced (U), is in voicing transition (T), is invalid (I), or is voiced. If voiced, the decoded value shall be used as the pitch period (8,000 Hz sampling frequency divided by pitch frequency).

Code	Pitch Period	Code	Pitch Period	Code	Pitch Period	Code	Pitch Period	Code	Pitch Period
0	(U)	26	58	52	50	78	96	104	140
1	(U)	27	22	53	40	79	(I)	105	(I)
2	(U)	28	(I)	54	48	80	(I)	106	136
3	(I)	29	24	55	(I)	81	74	107	(I)
4	(U)	30	28	56	54	82	70	108	144
5	(I)	31	(I)	57	(I)	83	72	109	(I)
6	(I)	32	(U)	58	56	84	66	110	(I)
7	31	33	(I)	59	(I)	85	76	111	(T)
8	(U)	34	(I)	60	52	86	68	112	124
9	(I)	35	(I)	61	(I)	87	(I)	113	120
10	(I)	36	(I)	62	(I)	88	62	114	128
11	21	37	39	63	(T)	89	(I)	115	(I)
12	(I)	38	33	64	(U)	90	60	116	(I)
13	(I)	39	32	65	(I)	91	(I)	117	(I)
14	29	40	(I)	66	(I)	92	64	118	(I)
15	30	41	37	67	108	93	(I)	119	(T)
16	(U)	42	35	68	(I)	94	(I)	120	(I)
17	(I)	43	36	69	78	95	(T)	121	(I)
18	(I)	44	(I)	70	100	96	(I)	122	(I)
19	20	45	38	71	104	97	116	123	(T)
20	(I)	46	34	72	(I)	98	132	124	(I)
21	25	47	(I)	73	84	99	112	125	(T)
22	27	48	(I)	74	92	100	148	126	(T)
23	26	49	42	75	88	101	152	127	(T)
24	(I)	50	46	76	156	102	(I)		
25	23	51	44	77	80	103	(I)		

3.5 RMS Amplitude. Root-mean-square (RMS) preemphasized speech amplitude, scaled from 0-511 (i.e. 9 bits), shall be coded into 5 bits and decoded back to 9 bits as shown in the following table. When decoding, interpolation should be used to obtain intermediate values.

From	To	Code	Decode	From	To	Code	Decode
0	0	0	0	31	35	16	32
1	1	1	1	36	42	17	39
2	2	2	2	43	51	18	46
3	3	3	3	52	60	19	55
4	4	4	4	61	72	20	66
5	5	5	5	73	86	21	79
6	6	6	6	87	103	22	94
7	7	7	7	104	123	23	113
8	8	8	8	124	147	24	135
9	10	9	9	148	176	25	164
11	12	10	11	177	210	26	192
13	14	11	13	211	251	27	230
15	17	12	16	252	300	28	275
18	21	13	19	301	359	29	328
22	25	14	23	360	428	30	392
26	30	15	27	429	511	31	468

3.6 Reflection Coefficients

3.6.1 Reflection Coefficients 1 and 2. The first Reflection Coefficient (RC1) shall be coded as 5 bits. Coding and decoding shall be as shown in the following table. The second Reflection Coefficient (RC2) shall be coded and decoded the same as RC1. Note that coded values are the index numbers expressed in binary "two's complement". Also, sign convention is such that RC1 = R_1/R_0, where R_1 and R_0 are autocorrelation functions with sample delays of 1 and 0 respectively. These conventions are used for all reflection coefficients.

From	To	Code	Index	Decode
-.9999	-.9844	10001	-15	-.9844
-.9843	-.9688	10010	-14	-.9688
-.9687	-.9531	10011	-13	-.9531
-.9530	-.9375	10100	-12	-.9375
-.9374	-.9063	10101	-11	-.9218
-.9062	-.8750	10110	-10	-.8906
-.8749	-.8281	10111	-9	-.8438
-.8280	-.7656	11000	-8	-.7812

(Continued)

From	To	Code	Index	Decode
-.7655	-.6875	11001	-7	-.7187
-.6874	-.6094	11010	-6	-.6406
-.6093	-.5313	11011	-5	-.5625
-.5312	-.4219	11100	-4	-.4688
-.4218	-.3125	11101	-3	-.3593
-.3124	-.2032	11110	-2	-.2500
-.2031	-.0938	11111	-1	-.1406
-.0937	+.0937	00000	0	+.0313
.0938	.2031	00001	1	.1406
.2032	.3124	00010	2	.2500
.3125	.4218	00011	3	.3593
.4219	.5312	00100	4	.4688
.5313	.6093	00101	5	.5625
.6094	.6874	00110	6	.6406
.6875	.7655	00111	7	.7187
.7656	.8280	01000	8	.7812
.8281	.8749	01001	9	.8438
.8750	.9062	01010	10	.8906
.9063	.9374	01011	11	.9218
.9375	.9530	01100	12	.9375
.9531	.9687	01101	13	.9531
.9688	.9843	01110	14	.9688
.9844	.9999	01111	15	.9844

3.6.2 Reflection Coefficient 3. The third Reflection Coefficient (RC3) shall be coded as 5 bits. Coding and decoding shall be as shown in the following table.

From	To	Code	Index	Decode
-.9999	-.5891	10000	-16	-.6033
-.5890	-.5456	10001	-15	-.5598
-.5455	-.5019	10010	-14	-.5164
-.5018	-.4583	10011	-13	-.4729
-.4582	-.4148	10100	-12	-.4295
-.4147	-.3712	10101	-11	-.3860
-.3711	-.3276	10110	-10	-.3426
-.3275	-.2840	10111	-9	-.2991
-.2839	-.2404	11000	-8	-.2557
-.2403	-.1967	11001	-7	-.2122
-.1966	-.1532	11010	-6	-.1687
-.1531	-.1096	11011	-5	-.1253
-.1095	-.0660	11100	-4	-.0818
-.0659	-.0224	11101	-3	-.0384
-.0223	.0212	11110	-2	.0051
.0213	.0648	11111	-1	.0485
.0649	.1139	00000	0	.0920
.1140	.1575	00001	1	.1355
.1576	.2011	00010	2	.1789
.2012	.2447	00011	3	.2224
.2448	.2883	00100	4	.2658
.2884	.3318	00101	5	.3093
.3319	.3755	00110	6	.3527
.3756	.4191	00111	7	.3962
.4192	.4626	01000	8	.4396
.4627	.5062	01001	9	.4831
.5063	.5499	01010	10	.5266
.5500	.5934	01011	11	.5700
.5935	.6370	01100	12	.6135
.6371	.6807	01101	13	.6569
.6807	.7242	01110	14	.7004
.7243	.9999	01111	15	.7438

3.6.3 Reflection Coefficient 4. The fourth Reflection Coefficient (RC4) shall be coded as 5 bits. Coding and decoding shall be as shown in the following table.

From	To	Code	Index	Decode
-.9999	-.7627	10000	-16	-.7774
-.7626	-.7236	10001	-15	-.7383
-.7236	-.6846	10010	-14	-.6993
-.6845	-.6455	10011	-13	-.6602

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From	To	Code	Index	Decode
-.6454	-.6065	10100	-12	-.6211
-.6064	-.5674	10101	-11	-.5821
-.5673	-.5283	10110	-10	-.5430
-.5282	-.4893	10111	-9	-.5040
-.4892	-.4502	11000	-8	-.4649
-.4501	-.4112	11001	-7	-.4258
-.4111	-.3721	11010	-6	-.3868
-.3720	-.3330	11011	-5	-.3477
-.3329	-.2940	11100	-4	-.3086
-.2939	-.2549	11101	-3	-.2696
-.2548	-.2158	11110	-2	-.2305
-.2157	-.1768	11111	-1	-.1914
-.1767	-.1329	00000	0	-.1524
-.1328	-.0938	00001	1	-.1133
-.0937	-.0548	00010	2	-.0743
-.0547	-.0157	00011	3	-.0352
-.0156	.0234	00100	4	.0039
.0235	.0624	00101	5	.0429
.0625	.1015	00110	6	.0820
.1016	.1405	00111	7	.1211
.1406	.1796	01000	8	.1601
.1797	.2187	01001	9	.1992
.2188	.2577	01010	10	.2382
.2578	.2968	01011	11	.2773
.2969	.3359	01100	12	.3164
.3360	.3749	01101	13	.3554
.3750	.4140	01110	14	.3945
.4141	.9999	01111	15	.4336

3.6.4 Reflection Coefficient 5. The fifth Reflection Coefficient (RC5), used when a frame is voiced, shall be coded as 4 bits. Coding and decoding shall be as shown in the following table.

From	To	Code	Index	Decode
-.9999	-.6047	1000	-8	-.6358
-.6046	-.5324	1001	-7	-.5635
-.5323	-.4600	1010	-6	-.4912
-.4599	-.3877	1011	-5	-.4190
-.3876	-.3153	1100	-4	-.3467
-.3152	-.2430	1101	-3	-.2744
-.2429	-.1707	1110	-2	-.2022
-.1706	-.0984	1111	1	-.1299
-.0983	-.0214	0000	0	-.0577
-.0213	.0509	0001	1	.0146
.0510	.1232	0010	2	.0869
.1233	.1955	0011	3	.1591
.1956	.2679	0100	4	.2314
.2680	.3403	0101	5	.3037
.3404	.4126	0110	6	.3759
.4127	.9999	0111	7	.4482

3.6.5 Reflection Coefficient 6. The sixth Reflection Coefficient (RC6), used when a frame is voiced, shall be coded as 4 bits. Coding and decoding shall be as shown in the following table.

From	To	Code	Index	Decode
-.9999	-.7011	1000	-8	-.7315
-.7010	-.6328	1001	-7	-.6631
-.6327	-.5645	1010	-6	-.5948
-.5644	-.4962	1011	-5	-.5264
-.4961	-.4279	1100	-4	-.4581
-.4278	-.3596	1101	-3	-.3897
-.3595	-.2913	1110	-2	-.3213
-.2912	-.2230	1111	-1	-.2530
-.2229	-.1505	0000	0	-.1846
-.1504	-.0822	0001	1	-.1162
-.0821	-.0139	0010	2	-.0479
-.0138	.0544	0011	3	.0205
.0545	.1227	0100	4	.0888

(Continued)

From	To	Code	Index	Decode
.1228	.1910	0101	5	.1572
.1911	.2593	0110	6	.2256
.2594	.9999	0111	7	.2939

3.6.6 Reflection Coefficient 7. The seventh Reflection Coefficient (RC7), used when a frame is voiced, shall be coded as 4 bits. Coding and decoding shall be as shown in the following table.

From	To	Code	Index	Decode
-.9999	-.5474	1000	-8	-.5762
-.5473	-.4809	1001	-7	-.5098
-.4808	-.4145	1010	-6	-.4434
-.4144	-.3480	1011	-5	-.3770
-.3479	-.2816	1100	-4	-.3106
-.2815	-.2152	1101	-3	-.2442
-.2151	-.1488	1110	-2	-.1778
-.1487	-.0824	1111	-1	-.1114
-.0823	-.0117	0000	0	-.0450
-.0116	.0547	0001	1	.0214
.0548	.1211	0010	2	.0878
.1212	.1875	0011	3	.1542
.1876	.2540	0100	4	.2206
.2541	.3204	0101	5	.2870
.3205	.3869	0110	6	.3534
.3870	.9999	0111	7	.4198

3.6.7 Reflection Coefficient 8. The eighth Reflection Coefficient (RC8), used when a frame is voiced, shall be coded as 4 bits. Coding and decoding shall be as shown in the following table.

From	To	Code	Index	Decode
-.9999	-.6242	1000	-8	-.6539
-.6241	-.5568	1001	-7	-.5865
-.5567	-.4895	1010	-6	-.5191
-.4894	-.4221	1011	-5	-.4517
-.4220	-.3548	1100	-4	-.3843
-.3547	-.2874	1101	-3	-.3169
-.2873	-.2201	1110	-2	-.2496
-.2200	-.1527	1111	-1	-.1822
-.1526	-.0811	0000	0	-.1148
-.0810	-.0138	0001	1	-.0474
-.0137	.0536	0010	2	.0200
.0537	.1209	0011	3	.0874
.1210	.1883	0100	4	.1548
.1884	.2556	0101	5	.2222
.2557	.3230	0110	6	.2895
.3231	.9999	0111	7	.3569

3.6.8 Reflection Coefficient 9. The ninth Reflection Coefficient (RC9), used when a frame is voiced, shall be coded as 3 bits. Coding and decoding shall be as shown in the following table.

From	To	Code	Index	Decode
-.9999	-.3077	100	-4	-.3634
-.3076	-.1908	101	-3	-.2462
-.1907	-.0738	110	-2	-.1290
-.0737	.0432	111	-1	-.0118
.0433	.1638	000	0	.1054
.1639	.2807	001	1	.2226
.2808	.3977	010	2	.3398
.3978	.9999	011	3	.4570

3.6.9 Reflection Coefficient 10. The tenth Reflection Coefficient (RC10), used when a frame is voiced, shall be coded as 2 bits. Coding and decoding shall be as shown in the following table.

From	To	Code	Index	Decode
-.9999	-.3117	10	-2	-.4043
-.3116	-.1203	11	-1	-.2129
-.1202	.0743	00	0	-.0215
.0744	.9999	01	1	.1699

3.7 Error Control Coding. When a frame is nonvoiced, a total of 20 bits shall be used for transmission error detection and correction. The four most significant bits of the RMS amplitude and first four reflection coefficients shall be protected by a four bit Error Control (EC) code as shown below (in hexadecimal form).

Data	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F
EC	0	7	B	C	D	A	6	1	E	9	5	2	3	4	8	F

3.8 Synthesis

3.8.1 Voiced Periods. Voiced speech shall be synthesized by a 10th order all-pole filter excited by pitch-synchronous pulses. The relative amplitudes of 40 recommended excitation values are shown in the following table.

Index	Amplitude	Index	Amplitude	Index	Amplitude	Index	Amplitude
1	249	11	-82	21	-82	31	-29
2	-262	12	376	22	-123	32	-21
3	363	13	288	23	-39	33	-18
4	-362	14	-65	24	65	34	-27
5	100	15	-20	25	64	35	-31
6	367	16	138	26	19	36	-22
7	79	17	-62	27	16	37	-12
8	78	18	-315	28	32	38	-10
9	10	19	-247	29	19	39	-10
10	-277	20	-78	30	-15	40	-4

Note that if the pitch period is equal to 40, the 40 excitation values should be used as pitch excitation throughout the pitch period. If the pitch period is greater than 40, the 40 excitation values should be used as pitch excitation, followed by zero values for the remainder of the pitch period. And, if the pitch period is less than 40 (i.e., between 20 and 39), all 40 excitation values should be used as pitch excitation. Those values remaining at the end of the current pitch period, scaled to reflect the RMS amplitude change between this pitch period and the next, should be added to the excitation values in the next pitch period. For example, if the pitch period is 38, excitation value 39 of one pitch period (scaled to reflect the RMS change between periods) would be added to excitation value 1 of the next pitch period.

3.8.2 Unvoiced Periods. Unvoiced speech shall be synthesized by a 4th order all-pole filter with pseudorandom or quasi-random excitation.

3.8.3 Transitional Periods. Speech in voicing transition shall be synthesized by an all-pole filter excited by pitch-synchronous pulses during the voiced part of the frame and excited with pseudorandom or quasi-random excitation during the unvoiced part of the frame. Typically, pitch, RMS amplitude, and reflection coefficients from the adjacent voiced and unvoiced frames are used in synthesizing the voiced and unvoiced parts.

3.8.4 De-emphasis. The de-emphasis digital transfer function (which provides both de-emphasis and filtering) shall be:

$$\frac{1}{1 - 0.75\,z^{-1}}$$

4. Effective Data. The use of this standard by U.S. government departments and agencies is mandatory effective 180 days following the date of this standard.

5. Changes. When a Government department or agency considers that this standard does not provide for its essential needs, a statement citing specific requirements shall be sent in duplicate to the General Services Administration (K), Washington, DC, 20405, in accordance with the provisions of the Federal Property Management Regulation 41 CFR 101-29.403-1. The General Services Administration will determine the appropriate action to be taken and will notify the agency.

PREPARING ACTIVITY:

National Communications System
Office of Technology and Standards
Washington, DC 20305

MILITARY INTERESTS:

Military Coordinating Activity
DCA -- DC

Review Activities
Army -- AD, CR
Navy -- AS, OM
RADC -- 26

Custodians
Army -- SC
Navy -- EC
Air Force -- 90
JTCO -- TT

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