Office of
Engineering and
Technology

Authorization
And Evaluation
Division

Federal
Communications
Commission

MULTICHANNEL TELEVISION SOUND

TRANSMIISSION AND AUDIO PROCESSING

REQUIREMENTS FOR THE BTSC SYSTEM

OET BULLETIN NO. 60
REVISION A

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PREFACE

This bulletin contains technical specifications for the BTSC System developed by the Electronics Industries Association, 2001 Eye Street, N.W. Washington, D.C. 20006. These specifications have been published pursuant to the Report & Order in BC Docket 21323 adopted March 29, 1984, and are guidelines for stations employing the BTSC system of multichannel sound transmission and audio processing.

The Commission in BC Docket 21323 has adopted very general technical rules that will allow the television aural baseband to be used for television stereophonic sound, second language programing and any other broadcast or non-broadcast use.

The BTSC System uses a pilot aural subcarrier at 15,734 Hz. The pilot allows receivers to recognize that transmissions are in stereo and to switch into the stereophonic reception mode. To ensure compatibility and to prevent BTSC type receivers from falsely detecting other MTS formats, FCC Rule § 73.682(c)(3) restricts emissions at 15,734 Hz. The purpose of this Bulletin is to give notice of the BTSC specifications referenced in §§ 73.681 and 73.682(c)(3) of the Commission's Rules.

Standards for the BTSC system as presented to the Federal Communications Commission by the Electronic Industries Association.

A. Definitions

Compandoring: A noise reduction process used in the stereophonic subchannel and the second audio program subchannel consisting of encoding (compression) before transmission and decoding (expansion) after reception. The specific BTSC encoding (compression) Algorithm is described in Section B.(c) and Figure 1 of this bulletin. BTSC decoding (expansion) is complementary to BTSC encoding.

Composite stereophonic baseband signal: The stereophonic sum modulating signal, the stereophonic difference encoded signal and the pilot subcarrier.

Crosstalk: An undesired signal occurring in one channel caused by an electrical signal in other channels.

Decibel ERMS value: The exponentially time-weighted root mean square (ERMS) value converted to dB as follows:

$$\text{decibel ERMS value} = 20 \log_{10}\frac{(\text{ERMS value})}{(\text{Reference})}$$

Where Reference is the 0dB ERMS value.

Encoding: See compandoring

Equivalent input separation: A method of specifying the stereophonic separation by referring variations from ideal at the output back to the input. To accomplish this, an input signal which causes a non-ideal output is varied by degrading input separation until the output conforms to the ideal. The amount of input separation degradation required is the equivalent input separation.

Equivalent modulation: See equivalent input tracking.

Equivalent input tracking: A method of specifying the tracking ability of the encoding process by referring variations from ideal at the output back to the input of the encoder. To accomplish this, an input signal which causes a non-ideal output is varied until the output conforms to the ideal. The amount of input variation required is the equivalent input tracking.

Exponentially time-weighted root mean square (ERMS) value:
The ERMS value of a waveform is obtained from the following
formula:

$$\text{ERMS value} = \sqrt{\frac{1}{T} \int_{-\infty}^{t} S^2(u)e^{-(t-u)/T}\,du}$$

Where S(u) is the waveform in question, a function of time,
T is the exponential time-weighing period, and t is the time
at which the ERMS value is computed.

Incidental carrier phase modulation (ICPM):
Angle modulation of the visual carrier by video signal
components which, when detected in TV receiver intercarrier
circuits, cause an audio interference known as intercarrier
buzz.

Left (or right) audio signal:
The electrical output of a microphone or combination of
microphones placed so as to convey the intensity, time, and
location of sounds originating predominately to the
listener's left (L) (or right (R)) of the center of the
performing area.

Left (or right) stereophonic channel:
The transmission path for the left (or right) audio signal.

Main channel:
The band of frequencies from 50 to 15,000 Hz which frequency
modulates the aural carrier.

Multichannel sound:
Multiplex transmission on the TV aural carrier.

Multiplex transmission: The simultaneous transmission of
the TV program main channel audio signal and one or more
subchannel signals. The subchannels include a stereophonic
subchannel, a second audio program subchannel, a non-program
related subchannel and a pilot subcarrier.*

Non-program related subchannel: The subchannel for the
multiplex transmission of a frequency-modulated subcarrier
for telemetry or other purposes.

* FCC NOTE: The Commission does not require nor restrict the use of the
second audio program subchannel or the non-program related subchannel.

<u>Pilot subcarrier</u>: A subcarrier serving as the control signal for use in the reception of TV stereophonic sound broadcasts.

<u>Second audio program (SAP) broadcast</u>: The multiplex transmission of a second audio program utilizing the second audio program subchannel.

<u>Second audio program (SAP) subchannel</u>: The channel containing the frequency-modulated second audio program subcarrier.

<u>Second program audio signal</u>: The monophonic audio signal delivered to the SAP encoder.

<u>Second program encoded signal</u>: The second program audio signal after encoding.

<u>75 microsecond (75us) equivalent modulation</u>: The audio signal level prior to encoding that results in a stated percentage modulation when the encoding process is replaced by 75us pre-emphasis.

<u>Spectral compression</u>: A process wherein variations in spectral content of an audio signal are reduced by varying a frequency filtering function applied to the signal in response to variations in the spectral content of the signal.

<u>Stereophonic difference audio signal</u>: The left audio signal minus the right audio signal (L-R).

<u>Stereophonic difference encoded signal</u>: The stereophonic difference audio signal after encoding.

<u>Stereophonic separation</u>: The ratio of the electrical signal caused in the right (or left) stereophonic channel to the electrical signal caused in the left (or right) stereophonic channel by the transmission of only a right (or left) signal.

<u>Stereophonic sum audio signal</u>: The left audio signal plus the right audio signal (L+R).

<u>Stereophonic sum channel compensation</u>: A process wherein the phase and amplitude response resulting from bandlimiting in the process of encoding the stereophonic difference audio signal (which, if uncompensated, would detrimentally affect stereo separation) is compensated by an identical phase and amplitude response applied to the stereophonic sum audio signal.

Stereophonic sum modulating signal: The stereophonic sum
audio signal after compensation, pre-emphasis and other
processing.

Stereophonic subcarrier: A subcarrier having a frequency
which is the second harmonic of the pilot subcarrier
frequency and which is employed in TV stereophonic sound
broadcasting.

Stereophonic subchannel: The subchannel containing the
stereophonic subcarrier and its associated sidebands.

Wideband amplitude compression: A process wherein the
dynamic range of an audio signal is compressed by
simultaneously varying the gain of all audio frequencies
equally.

B. Transmission Standards

   (a)   Television stereophonic sound standards

      (1)   Television broadcast stations may transmit stereophonic
            sound by employing a subcarrier on the aural carrier. The
            main channel modulating signal shall be the stereophonic sum
            modulating signal; the subcarrier modulation shall be the
            stereophonic difference encoded signal.

      (2)   The subcarrier shall be the second harmonic of a pilot
            signal which is transmitted at a frequency equal to the
            horizontal line rate. Note: If the station is engaged in
            stereophonic sound transmission accompanied by monochrome
            picture transmission the horizontal scanning frequency shall
            be 15,734 Hz $\pm$ 2 Hz.

      (3)   The subcarrier shall be double sideband amplitude modulated
            with suppressed carrier and shall be capable of accepting a
            stereophonic difference encoded signal over a range of 50 –
            15,000 Hz.

      (4)   The total modulation of the aural carrier, including that
            caused by all subcarriers, shall comply with the
            requirements of §73.682(c) of the FCC Rules and Regulations.

   (b)   Television second audio program standards.

      (1)   Television broadcast stations may transmit a subcarrier
            carrying a second audio program.

      (2)   The subcarrier frequency shall nominally be equal to the
            fifth harmonic of the horizontal line rate.

      (3)   The second program encoded signal shall frequency modulate
            the subcarrier to a peak deviation of $\pm$ 10 kHz.

(4) The second audio program subchannel shall be capable of accepting second program encoded signals over a range of 50 - 10,000 Hz.

(5) The modulation of the aural carrier by the second audio program subcarrier shall comply with Section D(b)(4) of this bulletin (± 15 kHz deviation).

(c) Television sound encoding standards.

(1) The stereophonic difference audio signal and the second program audio signal shall be encoded prior to modulating their respective subcarriers.* A diagram of one method of obtaining this encoding is shown as Figure 1.

(2) This encoding shall have the following characteristics, where f is expressed in kilohertz (kHz).

(i) Fixed pre-emphasis (F(f)) whose transfer function is as follows:

$$F(f) = \frac{(jf/0.408)+1}{(jf/5.23)+1} \cdot \frac{(jf/2.19)+1}{(jf/62.5)+1}$$

(ii) Wideband amplitude compression wherein:

(a) The decibel gain (or loss) applied to the audio signal during encoding is equal to minus one times the decibel ERMS value of the encoded signal (the result of the encoding process), weighted by a transfer function (P(f)) as follows:

$$P(f) = \frac{(jf/0.0354)}{jf/0.0354)+1) \quad ((jf/2.09)+1)}$$

(b) The exponential time weighting period T_1 of the ERMS detector referred to above in (a) is 34.7 ms.

(c) The zero decibel reference ERMS value for the encoded signal referred to above in (a) is 8.99% modulation of the subcarrier at 0.300 kHz.

Note: This reference results in 0 dB gain through the encoding process at approximately 14.1% modulation using a 0.300 kHz tone, when overmodulation protection and the output bandlimiting filter (see (iv) and (v) following) gain is 0 dB at 0.300 kHz.

* FCC NOTE: When the SAP channel is used for non-program related audio signals, encoding is not specified.

(iii) Spectral compression wherein:

(a) The transfer function S(f,b) applied to the audio signal during encoding is:

$$S(f,b) = \frac{1 + (jf/F)\,(b+51)/(b+1)}{1 + (jf/F)\,(1+51b)/(b+1)} \quad , \quad \text{where } b = 10^{D/20}$$

F=20.1 kHz; D=decibel rms value and b is the decibel ERMS value of the encoded signal (the result of the encoding process) weighted according to a frequency transfer function Q (f) as follows:

$$Q(f) = \frac{(jf/5.86)^3}{((jf/7.66)^2 + (jf/7.31)+1) \cdot ((jf/26.9)+1) \cdot ((jf/3.92)+1)}$$

(b) The exponential time weighting period T_2 of the ERMS detector referred to above in (iii-a) is 11.4ms.

(c) The ERMS zero decibel reference for the encoded signal referred to above in (iii-a) is 5.16% modulation of the subcarrier at 8 kHz.

Note: This reference results in +18.4 dB gain through the encoding process at at approximately 32.0% modulation using a 8 kHz tone, when the overmodulation protection and the output bandlimiting filter (see (iv) and (v) following) gain is 0 dB at 8 kHz.

(iv) Overmodulation protection which functionally follows the functions i, ii, & iii above.

(v) Bandlimiting to appropriately restrict bandwidth which functionally follows the functions i, ii, & iii above.

(d) Television non-program related aural subcarrier standards.

(1) Multiplexing of the aural carrier is subject to the requirements of Section 73.682(c) of the FCC Rules and Regulations; provided, however, that when the stereophonic and/or second audio program subchannels are transmitted, multiplexing of the aural carrier by non-program related subchannels is subject to the following changes:

(i) The maximum modulation of the aural carrier by the non-program related subcarrier shall comply with the requirements of Section D(b)(5) of this bulletin.

      (ii)   When the stereophonic and second audio program subcarriers are transmitted, the instantaneous frequency of the non-program related subcarrier shall have the average value of six and one half times the horizontal scanning frequency with a tolerance of $\pm$ 500 Hz.

      (iii)   When only the stereophonic subcarrier is transmitted, the instantaneous frequency of the non-program related subcarrier shall lie between 47 and 120 kHz with a tolerance of $\pm$ 500 Hz.

C. Transmission System Requirements/Multichannel Sound Requirements 1/

    (a) Electrical performance standards for stereophonic operation:

      (1)   The aural transmitter must operate satisfactorily with a frequency deviation of $\pm$ 73 kHz. It is recommended that the transmitter operate satisfactorily with a frequency deviation of $\pm$ 100 kHz.

      (2)   The pilot subcarrier shall be frequency locked to the horizontal scanning frequency of the transmitted video signal.

      (3)   The requirements of Section 73.687(b)(1) of the FCC Rules and Regulations shall be complied with for both the (L+R) main channel and (L-R) subchannel, except for pre-emphasis as specified in Section B(c) of this Bulletin, with the additional requirement that the aural transmitter shall be capable of transmitting a band of frequencies from 50 to 120,000 Hz.

      (4)   During a time period in which a left only applied signal is positive, the main channel modulation shall cause an upward deviation of the aural carrier; and the stereophonic subcarrier, being the second harmonic of the pilot subcarrier, shall cross the time axis with a positive slope simultaneously with each crossing of the time axis by the pilot subcarrier. The stereophonic subcarrier shall cross the time axis at points located within $\pm$ 3 degrees (approximately $\pm$ 0.53 microseconds) of the zero crossings of the pilot subcarrier.

      (5)   The unmodulated stereophonic subcarrier shall be suppressed to a level less than 0.25 kHz deviation of the main carrier.

1/ Unless otherwise specified, the transmission system requirements are defined for 75us pre-emphasis (which is matched to that in the main channel in the case of stereophonic transmission) substituted for encoding. Measurements are made over the band of 50 to 15,000 Hz and employ 75us de-emphasis in the measuring equipment.

(6)   The combined audio frequency harmonics measured at the output
        of the transmitting system (including the sound encoder) at
        any audio frequency from 50 - 15,000 Hz and at modulating
        percentages of 25, 50 and 100%, 75us equivalent modulation
        shall not exceed the rms values in the following table:

50 to 100 Hz	3.5%
100 to 7,500 Hz	2.5%
7,500 to 15,000 Hz	3.0%

        Harmonics shall be included to 30 kHz.

(7)   The ratio of peak main channel deviation to the peak
        stereophonic subchannel deviation (without encoding) when only
        a steady state left (or right) signal exists shall nominally
        be one half for all levels of this signal and for all
        frequencies from 50 - 15,000 Hz.

(8)   The phase and amplitude characteristics of the stereophonic
        sum modulating signal and the stereophonic difference encoded
        signal shall be such that the minimum equivalent input
        separation at 10%, 75us equivalent modulation is as follows:

        (i)   30dB separation from 100 Hz to 8 kHz.

        (ii)   Smoothly decreasing separation below 100 Hz, from 30 dB
                to 26 dB at 50 Hz.

        (iii)   Smoothly decreasing separation above 8 kHz, from 30 dB
                to 20 dB at 14 kHz.

        Note: It is recommended that the transmission system,
        excluding encoding, shall meet a 40 dB separation requirement
        when 75us pre-emphasis is substituted for sound encoding.

(9)   Crosstalk into the main channel caused by a signal in the
        stereophonic subchannel shall be at least 40 dB below 25 kHz
        main carrier deviation.

(10)   Crosstalk into the main channel caused by a non-stereophonic
        multiplex signal shall be at least 60 dB below 25 kHz aural
        carrier deviation.

(11)   Crosstalk into the stereophonic subchannel caused by a signal
        in the main channel shall be at least 40 dB below 50 kHz aural
        carrier deviation.

(12)   Crosstalk into the stereophonic subchannel caused by another
        multiplex signal shall be at least 60 dB below 50 kHz aural
        carrier deviation.

(13)   The aural transmitting system output frequency modulation noise level in band of 50 - 15,000 Hz (with de-emphasis) must be at least 58 dB below the audio level representing a frequency deviation of $\pm$ 25 kHz. The frequency modulation noise level in the stereophonic subchannel, after demodulation, in the band of 50 - 15,000 Hz (with de-emphasis) must be at least 55 dB below the audio level representing a frequency deviation of $\pm$ 50 kHz.

(14)   The pilot subcarrier-to-interference ratio, over a bandwidth of 1 kHz centered at the pilot subcarrier, shall be at least 30 dB.

(b)   Electrical performance standards for second program operation.

(1)   The aural transmitter frequency deviation capability must comply with the requirements of Section C(a)(1) of this Bulletin.

(2)   The aural transmitter modulation bandwidth capability shall comply with the requirements of Section C(a)(3) of this bulletin.

(3)   The unmodulated subcarrier shall be frequency locked to the fifth harmonic of horizontal line rate. When modulated, the center frequency shall nominally be that of the fifth harmonic of the horizontal line scanning frequency with a tolerance of $\pm$ 500 Hz.

(4)   Frequency modulation of the subcarrier shall be used.

(5)   The subcarrier shall be shut off when the second audio program subchannel is not in use.

(6)   The combined audio frequency harmonics measured at the output of the transmitting system (including the encoder) at any audio frequency from 50 - 10,000 Hz and at modulating percentages of 25, 50 and 100% 75us equivalent modulation shall not exceed the rms values in the following table.

50 to 100 Hz	3.5%
100 to 5,000 Hz	4.0%
5,000 to 10,000 Hz	3.0%

Harmonics shall be included to 20 kHz.

(7)   Crosstalk into the SAP subchannel caused by a signal in the main channel and/or in the stereophonic subchannel shall be at least 50 dB below full modulation of the SAP subcarrier ($\pm$ 10 kHz deviation) in the band of frequencies from 50 Hz to 10kHz.

(8)   The aural transmitting system output frequency modulation noise level after subcarrier demodulation must be at least 50 dB below the level representing full modulation of the SAP subcarrier ($\pm$ 10 kHz deviation) in the band of frequencies from 50 Hz to 10 kHz.

(c) Electrical performance standards for video transmission.

    (1) When the station is engaged in stereophonic sound transmission, or when the station transmits stereophonic sound and/or second audio program, a sine wave of 4.5 MHz introduced at the terminals of the transmitter which are normally fed the composite color picture signal shall produce a radiated signal having an amplitude (as measured with a diode on the RF transmission line supplying power to the antenna after the combination of visual and aural power) which is down at least 30 dB with respect to the signal produced by a sine wave of 200 kHz.

    (2) In the situation where stereophonic sound and/or a second audio program is transmitted, the following requirements shall be met: the incidental phase modulation of the visual carrier by video signals in the frequency band between 1 and 92 kHz shall be less than three degrees for carrier amplitude below 0.75 of the voltage at synchronizing peaks and less than 5 degrees for carrier amplitudes exceeding 0.75 of the voltage at synchronizing peaks.

(d) Electrical performance standards for sound encoding.

    (1) The equivalent input noise of the sound encoder, measured over a 15 kHz bandwidth, shall be more than 70 dB below the 100 Hz, 100% 75us equivalent modulation level.

    (2) The tracking characteristics of the sound encoder shall be such that the minimum equivalent input separation at modulation percentages from 1% to 100% 75us equivalent modulation is 26 dB from 100 Hz to 8 kHz.

D. Modulation Levels

(a) When only a monophonic audio signal is transmitted, the modulation of the aural carrier shall not exceed 25 kHz deviation on peaks of frequent recurrence, unless some other peak modulation level is specified.

(b) For stations transmitting more than one audio program channel the maximum modulation levels must meet the following limitations:

    (1) TV stations transmitting stereophonic sound signals must limit the modulation of the aural carrier by the stereophonic sum modulating signal to 25 kHz deviation on peaks of frequent recurrence.

    (2) TV stations transmitting stereophonic sound signals must limit the modulation of the aural carrier by the sum of stereophonic sum modulating signal and stereophonic difference encoded signal to 50 kHz deviation on peaks of frequent recurrence.

(3)   The modulation of the aural carrier by the stereophonic pilot
       signal shall be 5.0 kHz deviation with a tolerance of
       ± 0.5 kHz.

(4)   TV stations transmitting a second audio program must limit the
       modulation of the aural carrier by the SAP subcarrier to
       15 kHz deviation.

(5)   TV stations transmitting multiplex signals on the aural
       carrier for non-program related purposes must limit the
       modulation of the aural carrier by the arithmetic sum of all
       subcarriers, other than the stereophonic and second audio
       program, to 3 kHz deviation.

(6)   Total modulation of the aural carrier by multichannel sound
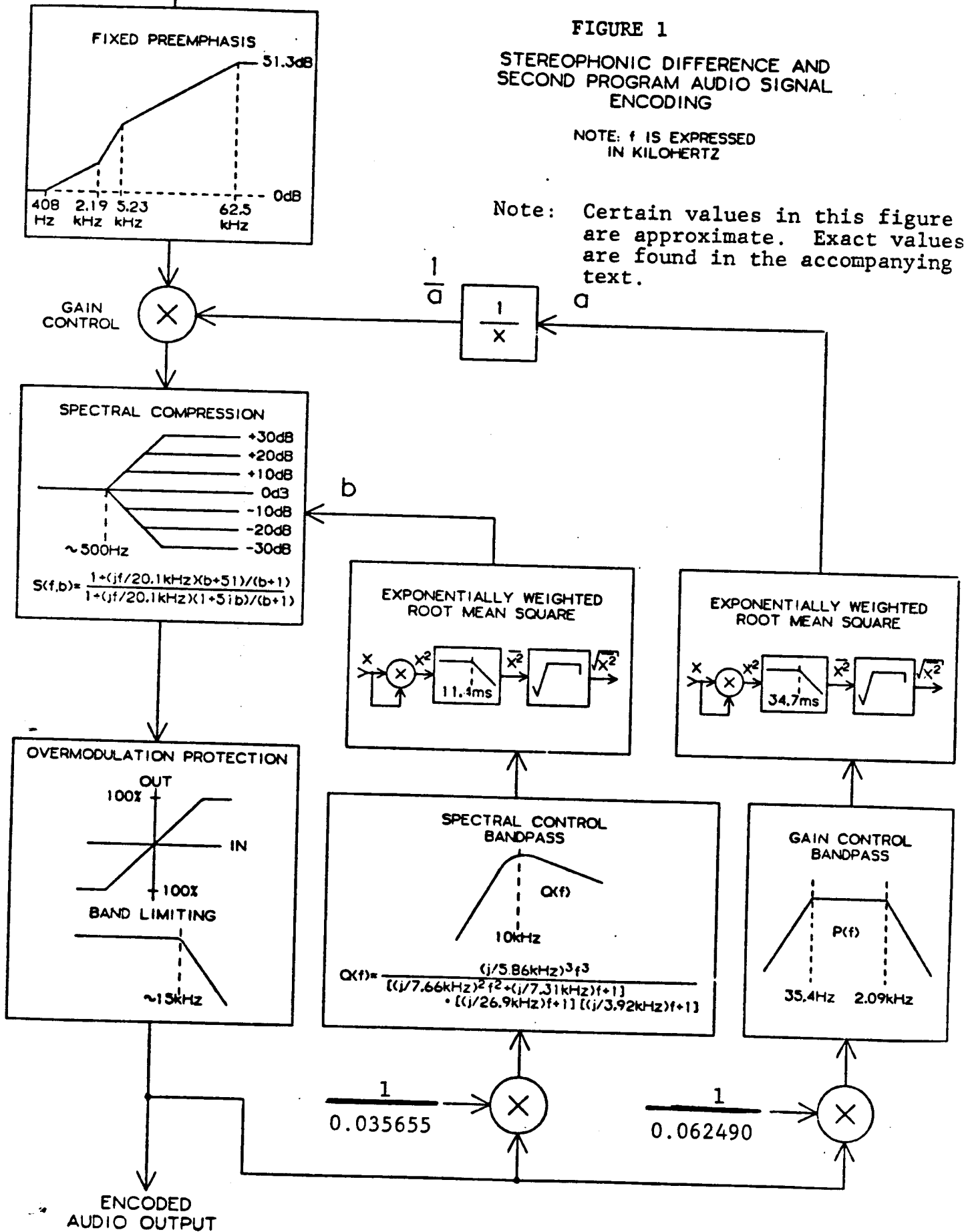   shall not exceed 73 kHz deviation.

AUDIO INPUT

FIXED PREEMPHASIS

51.3dB

0dB

408 Hz 2.19 kHz 5.23 kHz 62.5 kHz

GAIN CONTROL ⊗

$\frac{1}{a}$ $\frac{1}{X}$ a

FIGURE 1

STEREOPHONIC DIFFERENCE AND SECOND PROGRAM AUDIO SIGNAL ENCODING

NOTE: f IS EXPRESSED IN KILOHERTZ

Note: Certain values in this figure are approximate. Exact values are found in the accompanying text.

SPECTRAL COMPRESSION

+30dB
+20dB
+10dB
0d3
−10dB
−20dB
−30dB

~500Hz

$S(f,b) = \dfrac{1 + (jf/20.1\text{kHz} \times b + 51)/(b+1)}{1 + (jf/20.1\text{kHz})(1 + 5jb)/(b+1)}$

b

EXPONENTIALLY WEIGHTED ROOT MEAN SQUARE

x ⊗ x^2 11.4ms $\overline{x^2}$ $\sqrt{\overline{x^2}}$

EXPONENTIALLY WEIGHTED ROOT MEAN SQUARE

x ⊗ x^2 34.7ms $\overline{x^2}$ $\sqrt{\overline{x^2}}$

OVERMODULATION PROTECTION

OUT
100%
IN
+100%

BAND LIMITING

~15kHz

SPECTRAL CONTROL BANDPASS

Q(f)

10kHz

$Q(f) = \dfrac{(j/5.86\text{kHz})^3 f^3}{[(j/7.66\text{kHz})^2 f^2 + (j/7.31\text{kHz})f + 1]} \cdot [(j/26.9\text{kHz})f + 1][(j/3.92\text{kHz})f + 1]$

GAIN CONTROL BANDPASS

P(f)

35.4Hz   2.09kHz

$\dfrac{1}{0.035655}$ ⊗

$\dfrac{1}{0.062490}$ ⊗

ENCODED AUDIO OUTPUT

Section A on pages 1, Section B on page 4, 5, 6, and 7, Section C on pages 7, 8, 9, and 10, Section D on page 11, and Figure 1 on page 12 of OET Bulletin No. 60 are revised to read as follows:

Page	Section	Changes
1	A Definitions	Compandoring. Add a sentence: "The specific BTSC encoding (compression) algorithm is described in Sec. A (c) and Figure 1 of this Bulletin. BTSC decoding (expansion) is complementary to BTSC encoding."
1		Decibel ERMS value. Raise expression after log up one line to correct formula presentation.
4	B (a)(4)	Change Section 73.1570 to Section 73.682(c).
5	B (b)(5)	Correct the reference Section D(a)(1)(iv) to Section D(b)(4).
5	B (c)(2)(ii)(c)	Add underlined words to the note at the bottom of page 5: "This reference results in 0 dB gain through the encoding process at **approximately** 14.1% modulation using a 0.300 kHz tone, when the **overmodulation protection and** output bandlimiting filter (see (iv) and (v) following) gain is 0 dB at 0.300 kHz."
	B (c)(2)(iii)(c)	Correct the gain value on the **last** line of the note by changing 18.4 dB to 0 dB. Add underlined words to this note: "This reference results in +18.4 dB gain through the encoding process at **approximately** 32.0% modulation using an 8 kHz tone, when the **overmodulation protection and** output bandlimiting filter (see (iv) and (v) following) gain is 0 dB at 8 kHz."

Page	Section	Changes
7	B (d)(1)(i)	Correct the reference from Section D(a)(1)(vi) to Section D(b)(1).
	C (a)(3)	Change Section 73.687(b)(2) to Section 73.687(b)(1)
7	C (a)(4)	Paragraph has been rewritten to: "During a time interval in which a left only applied to signal is positive, the main channel modulation shall cause an upward deviation of the aural carrier and at each crossing of the time axis by the pilot subcarrier the modulated stereophonic subcarrier shall cross the time axis in a positive direction within +/- 3 degrees of the pilot subcarrier's period (approximately 0.53 microseconds)."
8	C (a)(6)	Reference to Section 73.687(b)(3), no longer in the rules, is identified as "pre-1983 version."
	C (a)(7)	After the word deviation on line 2, insert: (without encoding).
	C (a)(8)(iii)	Change 15 kHz to 14 kHz.
9	C (a)(14)	Change 40 dB to 30 dB.
	C (b)(7) & C (b)(8)	Add at the end of the sentence: "in the band of frequencies from 50 Hz to 10 kHz."
	C (b)(9)	Delete.
10	C (c)(1)	Delete reference to Section 73.687(a)(1) and (2)
11	D (b)(6)	Add the missing word "deviation" at the end of the sentence.
12	Figure 1	The gain constants at the bottom of the page are stated to two more significant figures. 0.357 becomes 0.35655 and 0.0625 becomes 0.062490. A note is added: "Certain values in this figure are approximate. Exact values are found in the accompanying text."