MEASUREMENTS AND OPERATIONAL ALIGNMENT OF TELEVISION TAPE–RECORDERS FOR BROADCASTING
Measurements on FM audio channels

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CONTENTS

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The EBU is publishing a series of documents on the subject of measurement techniques and operational alignment procedures for broadcast television tape–recorders. The documents which are planned at present will cover the following general topics:

Tech. 3219–1	–	*Alignment and calibration tapes (already published).*
Tech. 3219–2	–	*Operational alignment procedures (already published).*
Tech. 3219–3	–	*Special electrical measurements for television tape–recorders (in preparation).*
Tech. 3219–4	–	*Special mechanical measurements for television tape–recorders (already published).*
Tech. 3219–5	–	*Video measurement techniques for component analogue television tape–recorders (in preparation).*
Tech. 3219–6	–	*Audio measurement techniques for television tape–recorders with FM audio channels (the present document).*

This document, Tech. 3219/6, is the fourth to be published.

Introduction

This document describes the special and general electrical measurement techniques for the FM audio channels incorporated in component analogue television tape recorders, using the Betacam SP and MII formats, in use by EBU Members.

It is important that measurements are carried out in a consistent way to avoid difficulties during international programme exchanges. These techniques are based on the results of investigations conducted by EBU Sub–group G2 (Television tape–recording) and its Specialist Group G2/MES.

The Betacam SP and MII VTR formats have two audio channels which are recorded using frequency–division multiplex techniques within the video tracks of the colour–difference video channel. However, it is not possible to record or re–record these audio channels without also recording the video signals.

In all the systems so far encountered there is an integral noise reduction system which cannot be disabled. This is similar in principle to the dBx system with a 2:1 companding ratio. The interpretation of many of the results should take the effects of this companding system into account.

The use of FM recording techniques affects the nature of the impairments introduced by the record–replay process and hence some of the measurement techniques commonly used for other recording formats need to be changed to take this into account. In particular, the modulation noise, the intermodulation distortion and, to a lesser extent, the head–switch interference at a 50–Hz rate, are more significant impairments of the FM audio track.

An IEC Publication [1] covers this topic for domestic television cassette recorders, but the present publication covers the subject in a more suitable depth for broadcast use.

Chapter 1
FM audio system characteristics

1. Reference level

On the alignment tapes available for the formats covered by this document, Betacam SP and MII, the FM audio channels are recorded with the alignment tones given in *Table 1*. The alignment signal level has been chosen to be about 9 dB[1] below the permitted maximum signal level for peak programme signals[2]. These terms are defined in CCIR Recommendation 645 [2]

Table 1 – Alignment tones on Betacam SP and MII format calibration tapes

	Betacam SP	MII
Alignment tone	400 Hz	1000 Hz
FM deviation	± 25 kHz	± 35 kHz

Note: In an FM system, an increase in the recorded audio signal above the peak programme level will not, unless a limiter is incorporated, result in a rapid increase in harmonic distortion as would be the case in normal anhysteretic recording. Any over–deviation is more likely to have some effect on adjacent or overlapping FM channels.

2. Characteristic frequencies of the FM audio signal

The characteristic frequencies of the FM audio channels of the Betacam SP and MII formats are given in *Table 2*.

Table 2 – FM audio parameters of Betacam SP and MII

	Betacam SP	MII
Audio carrier (channel 1)	310 kHz	400 kHz
Audio carrier (channel 2)	540 kHz	700 kHz
Deviation (reference level)	± 25 kHz	± 35 kHz

1. Some organizations use a peak level which is 8 dB above the reference level.
2. When the programme peaks are measured by means of a programme meter, due account should be taken of the integration time of the instrument.

Chapter 2
Measurement methods

1. Gain and amplitude/frequency response of the playback channels

The gain and frequency response of the replay channels should be measured first, using the following procedure:

a) Replay the alignment tone section of the alignment tape (400 Hz for Betacam SP or 1000 Hz for MII) and adjust the audio replay level control to give the expected reading on the measuring instrument in use.

b) Replay the section of an audio alignment tape that contains a sequence of recorded frequencies and measure the output level at each frequency. This gives the playback amplitude/frequency response of the machine under test.

c) If the machine under test has a simultaneous replay head, then repeat steps a) and b) above using the signals from this head and adjusting its associated controls.

2. Gain and amplitude/frequency response of the record channel

Having made the measurements described in *Section 1.*, the playback gain controls must not subsequently be re–adjusted.

The record channel should be adjusted and measured in the following way:

a) Check the audio FM carrier frequencies using a spectrum analyser. During this check, the recorder should have no audio input signals but its audio inputs should be terminated with the impedance from which they are normally driven. Adjust the carrier frequencies if necessary.

b) Connect a black–level video signal to the video input of the recorder.

c) Connect a 1000 Hz tone at the alignment level to the audio channel under test and adjust the record gain control to give the same replay level as in *Section 1.a)* whilst the machine is in the E–E (direct electrical input to electrical output) mode.

d) Make a recording of this signal and verify that the level on replay is correct.

e) Make a recording of a series of frequencies at alignment level over the range of 20 Hz to 20 kHz. This may be conveniently done using an audio sweep signal. Replay this recording and measure the frequency response.

3. Harmonic distortion

The harmonic distortion is measured for recorded frequencies of 1000 Hz and 80 Hz at the alignment level and also at the peak recording level. The measurement can be made by means of a selective voltmeter which measures the amplitude of each harmonic spectrum line generated by the distortion process.

An alternative method which removes the fundamental frequency and measures the total harmonic distortion, THD, together with noise can be used. However this method will not be valid if the signal–to–noise ratio in the playback signal is so poor that the noise power becomes comparable with the power in the harmonic distortion components.

It should also be noted that automatic measuring equipment may use different frequencies to those specified above.

4. Intermodulation distortion

Intermodulation distortion can be measured by a method outlined in [3]. The procedure is as follows:

a) Connect a black–level video signal to the video input. Apply audio tones of 8.05 kHz and 12 kHz, each at 6 dB below peak level, simultaneously to the audio channel under test and make a recording.

b) Replay the recording and connect the audio channel under test to a noise measuring set via a 4–kHz band–pass filter. Intermodulation distortion, if present, will generate a 3.95–kHz component. The level of this component, expressed as a percentage of the input signal, is the intermodulation distortion.

c) The above test may be repeated with the two input tones at 6 dB below the alignment level.

d) Repeat the measurement on the other audio track.

5. Signal–to–noise ratio (idle–channel noise)

The signal–to–noise ratio of the FM audio channels can be measured using the following procedure:

a) Terminate the input of the machine with the impedance from which it is normally driven, and make a short recording of black–level video and silence.

b) Play back this recording and measure the audio signal at the machine output. This is the noise level, which it is customary to express as the signal–to–noise ratio with respect to the peak level.

The measuring equipment should conform to CCIR Recommendation 468–4 [4].

A more–searching evaluation of the machine performance can be obtained if both weighted and unweighted noise measurements are made. The same CCIR Recommendation specifies the frequency characteristics of a band–limiting filter for use in unweighted measurements.

6. Switching/modulation noise

This measurement determines the impairment caused by the presence of spurious signals which are accentuated when a modulating signal is present. The impairment is greater as the frequency of the modulating signal increases. The measurement is made as follows:

a) Connect a black–level video signal to the video input of the recorder.

b) Connect a 10–kHz signal at peak amplitude to the audio channel under test and make a recording.

c) Replay the recording and connect the signal to a noise measuring instrument conforming to CCIR Recommendation 468–4 via a 10–kHz notch filter. The measured value is then expressed as its ratio, in decibels, to the measured value of the modulating signal without the filter.

The spectral distribution of the modulation noise and, in particular, the low–frequency switching component, may be determined using a spectrum or frequency analyser.

7. Crosstalk between audio channels

Since it is not possible to separate the record processes of the video channel and the two FM audio channels, only the replay crosstalk between the FM audio tracks is considered to be relevant. It is measured in the following way:

a) Connect a black–level signal to the video input of the recorder.

b) Connect an audio sweep signal, or a sequence of single frequencies, at peak level to the input of the “A” channel. Terminate the input of the “B” channel with the impedance from which it is normally driven, and make a recording.

c) Replay the recording and measure on the output of the “B” channel the level of the crosstalk from the signal recorded on the “A” channel. The result is expressed relative to the peak level of the “B” channel, over the range of frequencies recorded.

d) Repeat the test for crosstalk from the “B” to the “A” channel.

8. Crosstalk from audio to video

Audio–to–video crosstalk may be detected and measured as follows:

a) Connect a black–level signal to the video input of the recorder.

b) Connect an audio sweep or “pink noise” signal at peak level to the inputs of both audio channels and make a recording.

c) Terminate the audio inputs to the recorder with the impedance from which they are normally driven and make a further recording.

d) Critically view the subsequent replay of the video output on a colour monitor. The visibility of any coloured low–level signals in the presence of the peak audio signals is due to crosstalk.

e) The level of this crosstalk may be measured using video noise measuring equipment. Measure the noise in the colour–difference channels during replay of the two sections of tape recorded in b) and c) above. Any difference in the measured noise is due to the audio–to–video crosstalk.

9. Crosstalk from video to audio

Video–to–audio crosstalk may be detected and measured as follows:

a) Terminate the inputs to both audio channels with the impedance from which they are normally driven. Make a recording of black–level video.

b) With the audio inputs still terminated, make a recording of a multiburst video signal on the luminance and colour–difference channels.

c) Replay the two recordings and carefully monitor the audio channels using a high–quality loudspeaker. Any difference in the audio noise level between the black–level and multiburst sections of the video recording indicates video–to–audio crosstalk.

d) This crosstalk may be measured using equipment conforming to CCIR Recommendation 468–4 [4]. Make audio noise measurements during the two recorded sequences. Any difference in the noise measurements is due to the video–to–audio crosstalk.

10. Wow and flutter

Wow and flutter measurements are carried out as follows:

a) Make a recording of a 3150–Hz tone at reference level.

b) Replay the recording and measure the fast and slow deviations of the reproduced frequency.

The method to be used is fully described in IEC Publication 386 [5].

A number of instruments for measuring this parameter are available commercially.

Wow and flutter should never be measured while simultaneously recording and reproducing.

11. Stereo performance

The performance parameters for stereo operation have been reviewed by the EBU. In general, there should be a close match between the gain, amplitude/frequency response and phase/frequency response of the two channels. The polarity of the two channels should be identical. Specific tolerances for these parameters for format B and format C VTRs are given in EBU Recommendation R44 [6]. These may be used as a guide.

12. Dynamics of the noise reduction system

The companding system can cause gain errors. These can be detected easily using a two–level tone burst signal; a suitable signal is shown in *Fig. 1a*. The measurement is made as follows:

a) Simultaneously record the two–level tone signal and a black–level video signal.

b) Replay the recording and measure the amplitude difference between the two portions of the tone burst. Any difference between this measurement and the difference between the two tones in the input signal should be noted.

The companding system can also cause transient distortion. The two–level tone burst signal is also suitable for checking this.

The method of measurement is as follows:

a) Monitor the tone–burst signal at the output of the compressor circuit. It will be of the form shown in *Fig. 1b*.

b) Make measurements of the "attack time", the "hold time", and the "recovery time" at the output of the compressor. Compare these with the values for these parameters given in the format specifications (reproduced in *Table 3*).

Since some of the above tolerances are quite wide, compatibility problems between recordings can be created.

A convenient method of checking this is to produce a local "sub master" tape with a recording of the two–level tone burst shown in *Fig. 1a*. If this is played back on a number of machines, the shape of the replayed tone bursts can be compared, and the variation of this parameter can be noted.

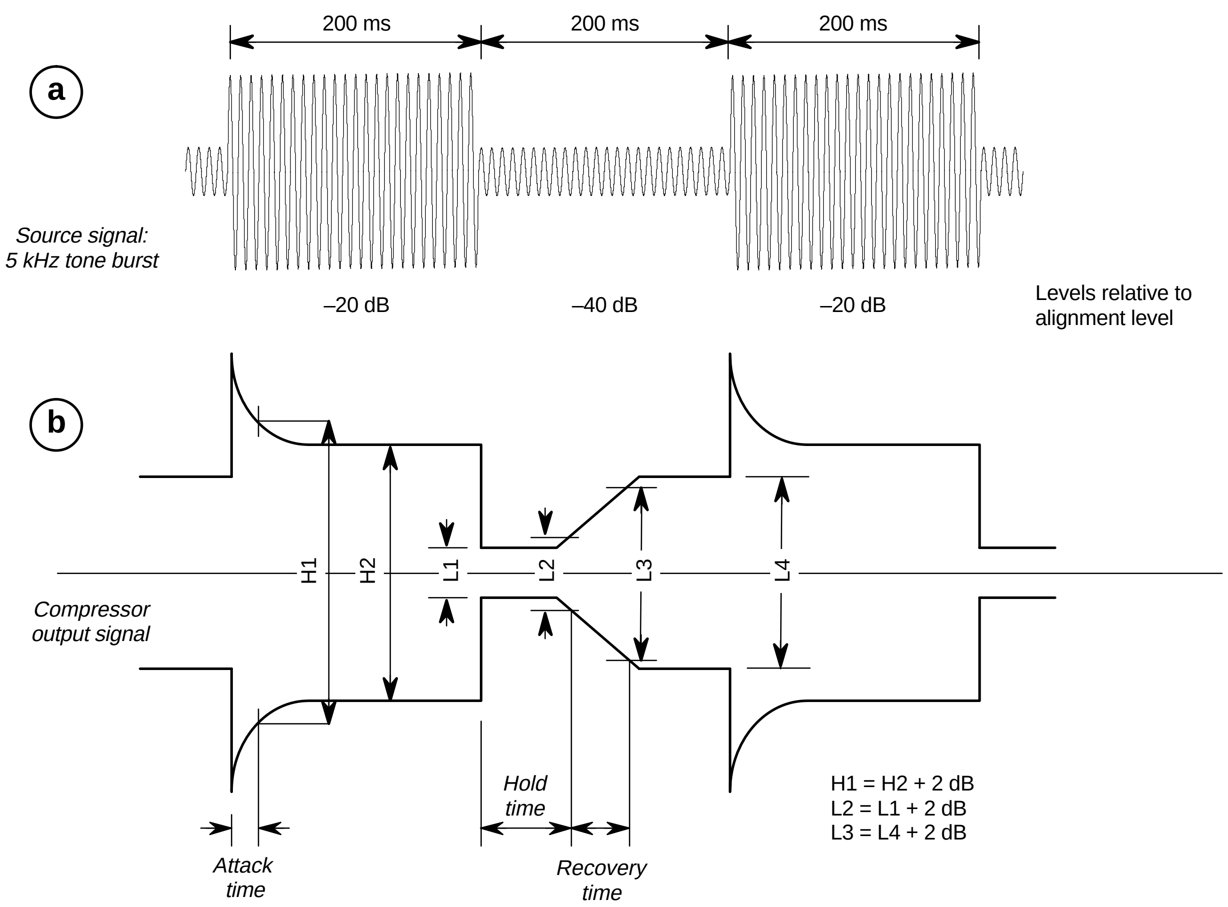

Fig. 1 – Measurement of the transient response of the noise–reduction system.

Table 3 – Noise–reduction transient response of the Betacam SP and MII formats.

	Betacam SP	MII
Attack time	1.8 ± 0.4 ms	9.0 ± 3.0 ms
Hold time	15.0 ± 3.0 ms	
Recovery time	40.0 ± 8.0 ms	90.0 ± 30 ms

13. Polarity tests

In order to determine the “absolute polarity” of a recorder, a suitable “alignment tape” is required. EBU Recommendation R50 [6] specifies that a positive–going waveform applied at pin 2 of the XLR input connector should cause an increase in the FM carrier frequency. Until a suitable test signal is developed which can easily be interpreted in the FM domain, the polarity at the input and output connectors is the only test that can be carried out. A suitable test signal for this is shown in *Fig. 2a*.

The test is carried out as follows:

a) Record the test signal on the track under test, together with a black–level video signal.

b) Connect the output connector of the audio track to an oscilloscope as shown in *Fig. 2b*. The displayed signal should be of the form shown in *Fig. 2c*.

The polarity should be the same in both the E–E and the replay modes of both channels.

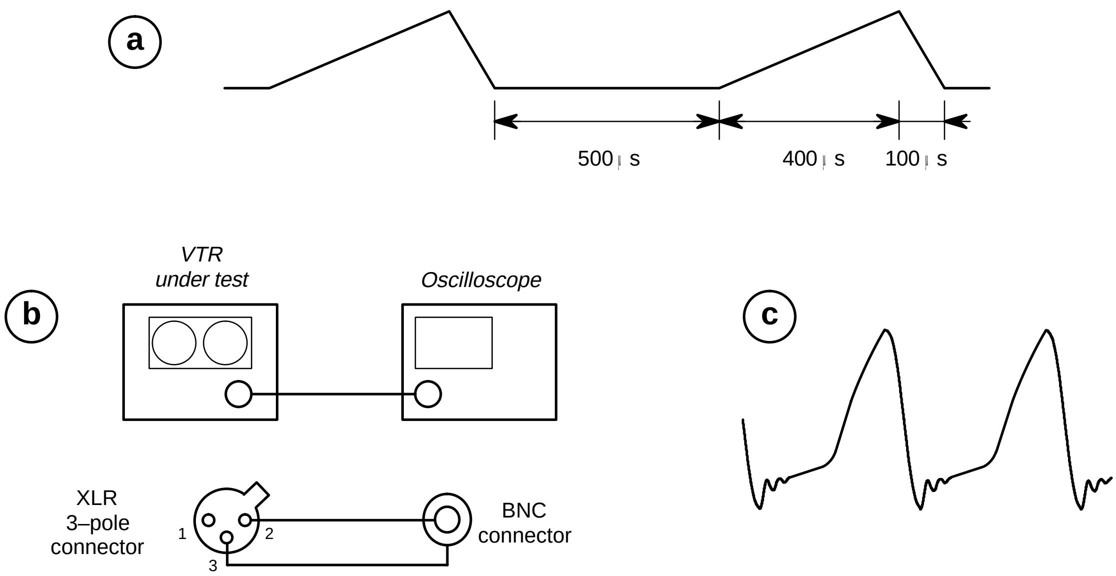

Fig. 2 – LF signal for audio polarity testing.

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[6] EBU Recommendation R44–1987: *Performance of sound channels 1 and 2 on format–B and format–C VTRs for stereo applications.*

[7] EBU Recommendation R50–1990: *Conservation of the polarity of audio signals in radio and television production installations.*

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