RECOMMENDATION ITU-R F.1111-1*

IMPROVED LINCOMPEX SYSTEM FOR HF RADIOTELEPHONE CIRCUITS

(Question ITU-R 146/9)

(1994-1995)

The ITU Radiocommunication Assembly,

considering

a) that, to maintain a satisfactory standard on international radiotelephone circuits operating at frequencies below 30 MHz and connected to the national network, it is necessary to compensate, at the transmitting end, for most, if not all, of the variations in the subscriber's speech volume and of the losses between the subscriber and the international exchange;

b) that, as a result, the circuit often operates under a condition of overall gain (two-wire to two-wire) and it is necessary to use a singing-suppressor to maintain stability;

c) that, the singing-suppressor markedly degrades the performance of the circuit, due to its switching action and its tendency to mis-operation by noise or interference on the radio path;

d) that the use of a singing-suppressor to maintain overall stability of the radiotelephone channel inhibits the interconnection, on a four-wire basis (see ITU-T Recommendation G.101), of radio circuits and long-distance cable or satellite circuits;

e) that, if HF radiotelephone circuits were operated at a nearly constant overall transmission loss, the singing-suppressor could be eliminated and a radio circuit could be integrated into an international chain;

f) that, to maintain a constant overall loss, while catering for variations in subscribers' speech volume and line loss, it is necessary to insert, at the receiving end of the circuit, a loss equivalent to the gain inserted at the transmitting end;

g) that the advantages of compandor operation, as used on some line transmission systems, are well established, but cannot be directly realized on a radio circuit subject to fading;

h) that, on such a radio circuit, an alternative means of conveying information as to the state of the compressor is necessary to control the expander;

j) that these alternative means enable advantage to be taken of a compression ratio in excess of that employed in line compandors, which is generally 2/1 or 4/1;

k) that the behaviour and advantages of a system employing a linked compressor and expander have been established as applicable to various communications environments; that for HF one administration has reported 22 dB average improvement across time for typical speech signals under varying propagation conditions with a maximum improvement of 47 dB;

l) that these system behaviour and advantages are desired for use with radio circuits having only modest frequency stabilities and various voice channel bandwidths;

m) that with such radio circuits loss of voice naturalness can occur as a result of end-to-end frequency error, and that in many cases it is not practical or possible to eliminate the error;

* This Recommendation should be brought to the attention of Radiocommunication Study Groups 8 and 10.

n) that such end-to-end frequency error has an adverse effect on system behaviour and advantages;

o) that the alternative means employed to convey compression information to the expander can also be used to eliminate the effect of end-to-end frequency errors and thereby provide system behaviour and advantages with voice naturalness;

p) that the alternative means employed to convey compression information to the expander and the speech compression band must both reside within available voice channel bandwidths;

q) that it is highly desirable that this system be interoperable with non-equipped stations for applications in networks handling mixed traffic;

r) that for applications wherein all stations are equipped with the system and interoperability is not an issue, the system receive end should maintain silence when no Lincompex signals are being received;

s) that with such an arrangement the two ends of a circuit will be complementary and the essential parameters of the system will have to be standardized,

recommends

1 that, wherever possible, HF radiotelephone circuits should be operated on the basis of a constant overall transmission loss (two-wire to two-wire) and that the system is equally applicable to full-duplex and half-duplex (simplex) circuits;

2 that a system comprising a compressor and expander linked by a control channel, which is separate from the speech channel and is resistant to fading distortion, should be used to achieve this performance (such a system is commonly known as Lincompex which is a convenient acronym for the phrase “linked compressor and expander”. Lincompex is neither a proprietary name nor does it refer to the manufacturer of a particular equipment); and that the control channel should be utilized to correct baseband frequency errors due to radio circuit equipment so as to provide the advantages of companding and natural voice for the majority of radio circuits;

3 that the system should maintain optimum loading of the transmitter at all times despite variations in subscribers’ speech volumes and line losses;

4 that the speech and control signals should both be contained within a single voice channel (the usable upper audio frequency of a voice channel in existing equipments is known to vary from 3 kHz to less than 2 kHz depending on equipment design) so that the system is generally applicable to any transmission medium which outputs a usable baseband signal;

5 that such a system should be in accordance with the description and parameters listed below:

5.1 General

For convenience, the performance requirements of this Recommendation are based on a system configuration (one end is shown in Fig. 1) which on the transmit side employs pre-compressor delay in conjunction with a voice-signal amplitude assessor. This does not preclude other configurations which meet the requirements. If desirable, a privacy device could be added within the circuit.

Four sets of specifications are presented to accommodate the most common voice channel bandwidths found in user equipments. When specifications differ between these sets, then each set is identified separately as (A), (B), (C), or (D). (A) provides interoperability with equipment conforming to Recommendation ITU-R F.455 (RF Series, Geneva, 1992).

5.2 Transmit side (Fig. 1a))

5.2.1 Speech channel

5.2.1.1 Steady-state conditions (compression and overall characteristics)

For input levels between +5 dBm0 to –55 dBm0 (see Note 1 at the end of § 5.8) the output should lie within the limits shown in Fig. 2.

FIGURE 1

Schematic diagram of system

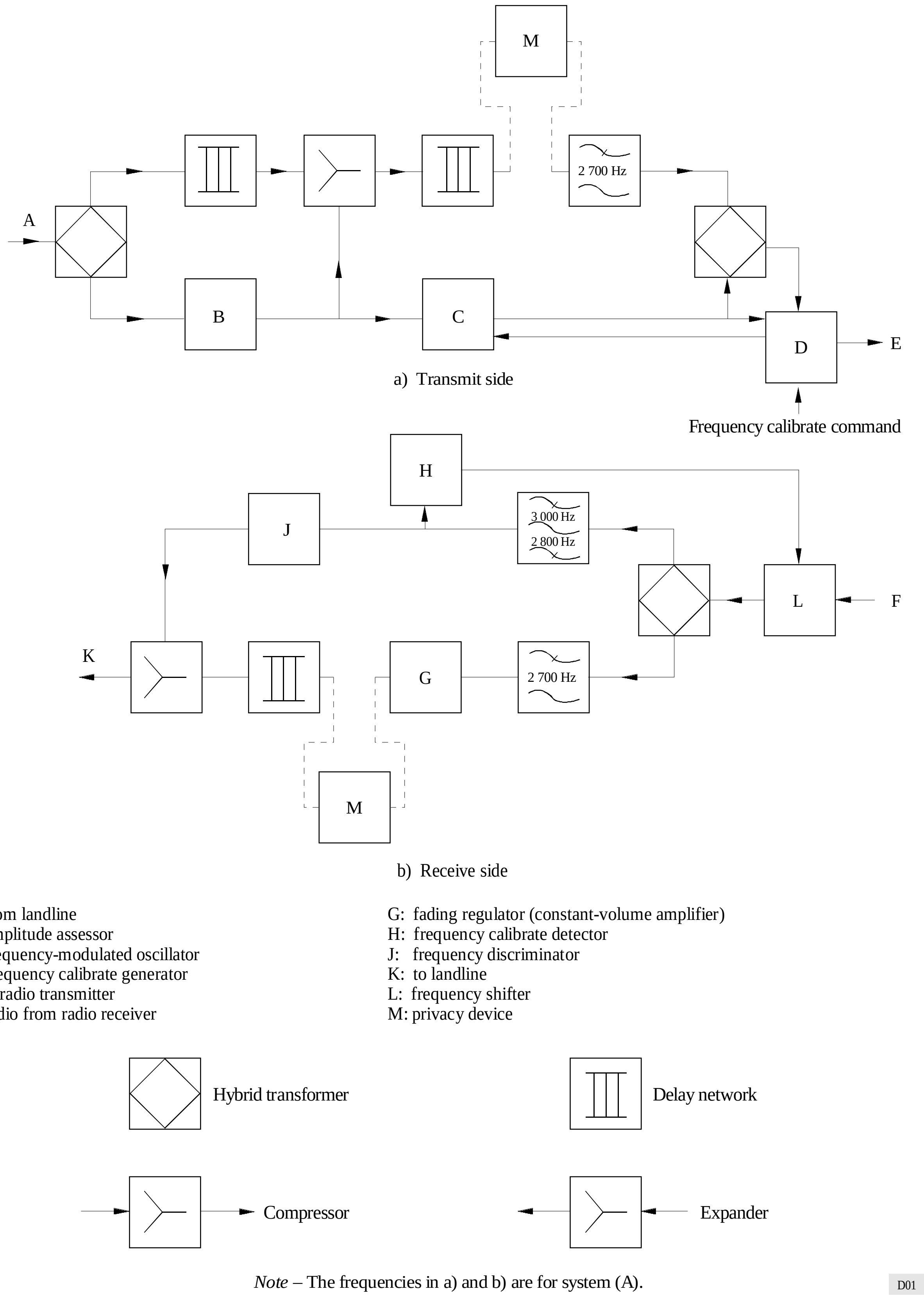
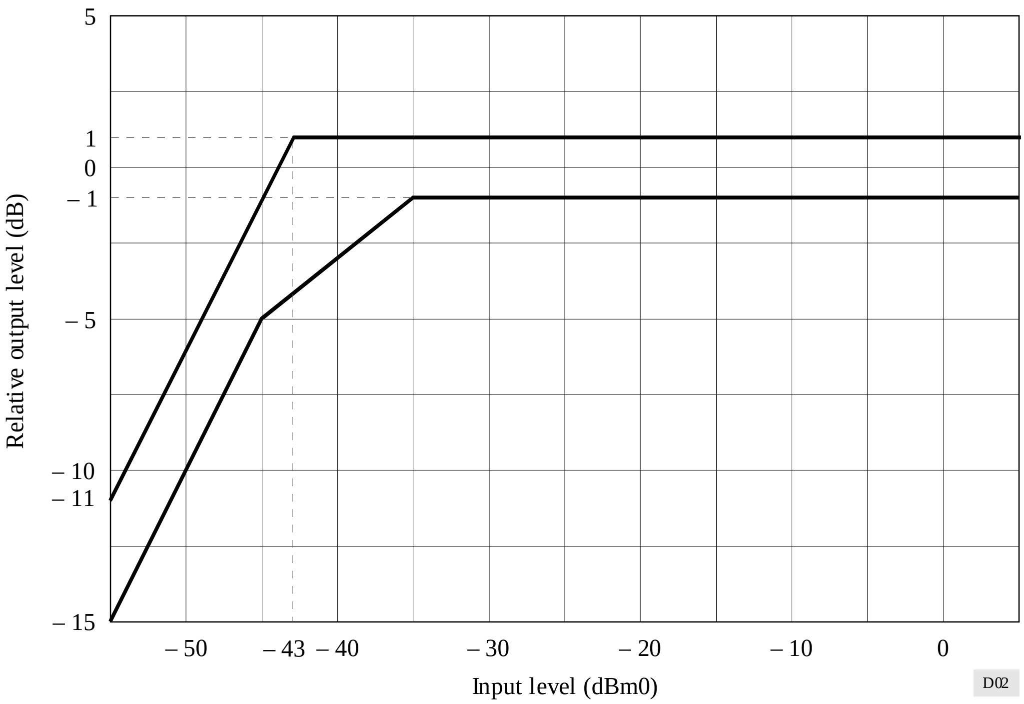


FIGURE 2

Input/output characteristic of transmit side



The overall amplitude/frequency response for the speech channel under both fixed-gain and assessor-controlled conditions at any level within the range + 5 dBm0 to –55 dBm0 should be in the range stated in Table 1.

TABLE 1

Amplitude/frequency response

System	A	B	C	D	Attenuation (dB)
Audio bandwidth (Hz)	250-2 500	250-2 380	250-2 000	250-1 575	
Frequency response (attenuation relative to the maximum response)	250-2 500	250-2 200	250-1 850	250-1 455	≤ 2
	2 500-2 700	2 200-2 380	1 850-2 000	1 455-1 575	≤ 6
	2 800 and above	2 480 and above	2 100 and above	1 675 and above	> 55
	250 and below				> 0

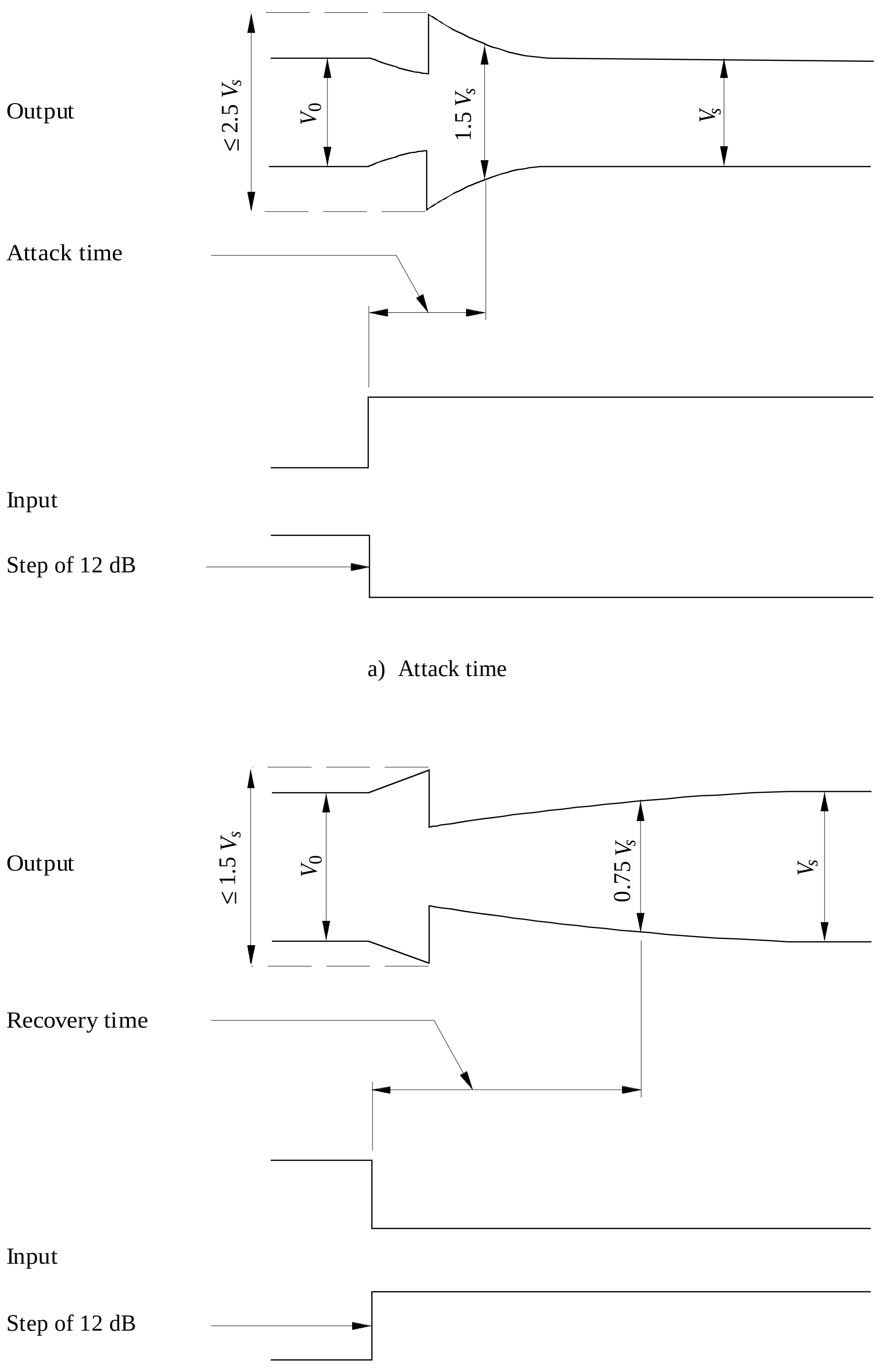
5.2.1.2 Transient response (overall, including amplitude assessor but excluding additional delay)

Attack time, Fig. 3a) (see Note 2 at the end of § 5.8) 07 ± 2 ms

Recovery time, Fig. 3b) (see Note 2 at the end of § 5.8) 20 ± 5 ms

FIGURE 3

Transient response of transmit side



a) Attack time

b) Recovery time

5.2.2 Control channel

Frequencies of frequency-modulated oscillator (frequency controlled by amplitude assessor output) are shown in Table 2.

TABLE 2

Frequency of frequency-modulated oscillator

System	A	B	C	D
Centre frequency (Hz)	2 900 ± 1	2 580 ± 1	2 200 ± 1	1 775 ± 1
Oscillator frequency resulting from an input level of 0 dBm0	50 Hz lower than the above			

Reference frequency deviation	± 60 Hz
Change of frequency for each 1 dB change of input level (see Fig. 4)	2 Hz
Input level to transmit side to produce nominal centre frequency	–25 dBm0
Oscillator frequency increase beyond that corresponding to –55 dBm0 when there is no input to the transmit side	> 0 Hz < 20 Hz
Oscillator frequency decrease beyond that corresponding to +5 dBm0 when the input to the transmit side exceeds +5 dBm0	> 0 Hz < 4 Hz
For sudden increases in the input that exceed 3 dB, the time taken for the oscillator to complete 80% of the corresponding change in frequency should be	6 ± 1 ms
For sudden decreases in the input that exceed 3 dB, the rate of change of oscillator frequency should be restricted to	2.5 ± 1.0 Hz/ms
Referenced to nominal centre frequency, the output spectrum should be effectively limited to	± 90 Hz
Output level relative to test tone level in the speech channel	–5 dB

5.2.3 Frequency calibrate

Upon command, the modulator shall generate the calibrate format shown in Fig. 5.

Envelope amplitude accuracy	± 1 dB
Envelope timing accuracy	± 0.5 ms
Overall format time	296 ms

5.2.4 Transmit modes

For operation enhancement and for interoperability with non-Lincompex stations, the following selectable transmit modes are defined:

– *Full Lincompex:* Calibrate may be sent.

– *Bypass with compression:* Same as full Lincompex except the control tone is attenuated 60 dB minimum at all times except during transmission of the calibrate format.

– *Bypass:* Same as bypass with compression except the compressor is made linear. Calibrate may be sent.

– *Wideband:* Same as bypass except that the speech bandwidth is 150-3 400 Hz within 2 dB. Speech filters are disabled. Calibrate may be sent.

FIGURE 4

Variation in frequency of the control tone with changes of input level to the transmit side

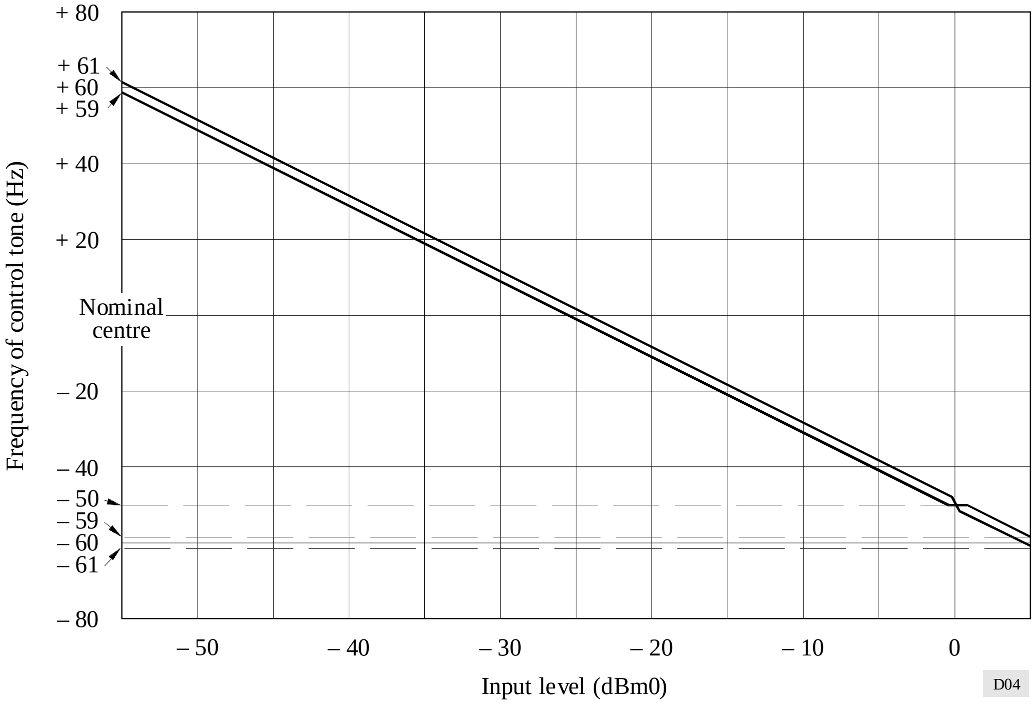
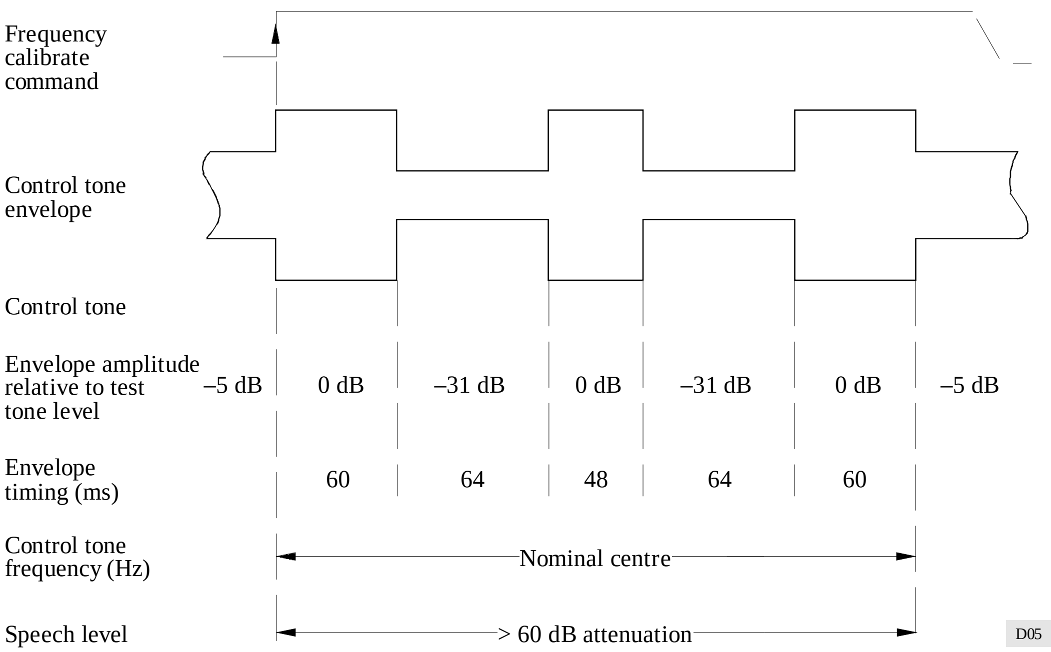


FIGURE 5

Modulator calibrate format



5.3 Receive side (Fig. 1b))

5.3.1 Speech channel

5.3.1.1 Steady-state conditions

The relative overall amplitude frequency response of the speech channel under fixed and controlled gain conditions should be in the range stated in Table 1.

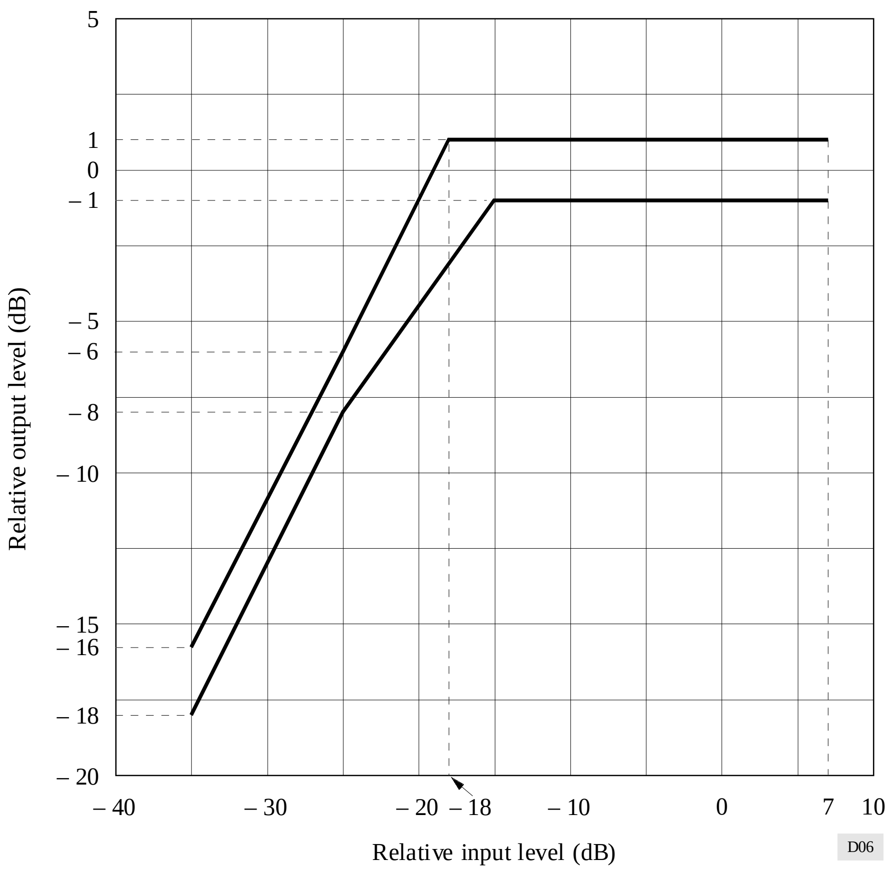
5.3.1.2 Fading regulator

5.3.1.2.1 Steady-state conditions

For input levels between + 7 dB and –35 dB, relative to the nominal design input level to the fading regulator, the output should be within the limits shown in Fig. 6. The nominal design input level which may vary between administrations is the value measured at the input of the fading regulator, under steady-state conditions, when 0 dBm0 is applied to the transmit side.

FIGURE 6

Input/output characteristic of fading regulator



5.3.1.2.2 Transient response

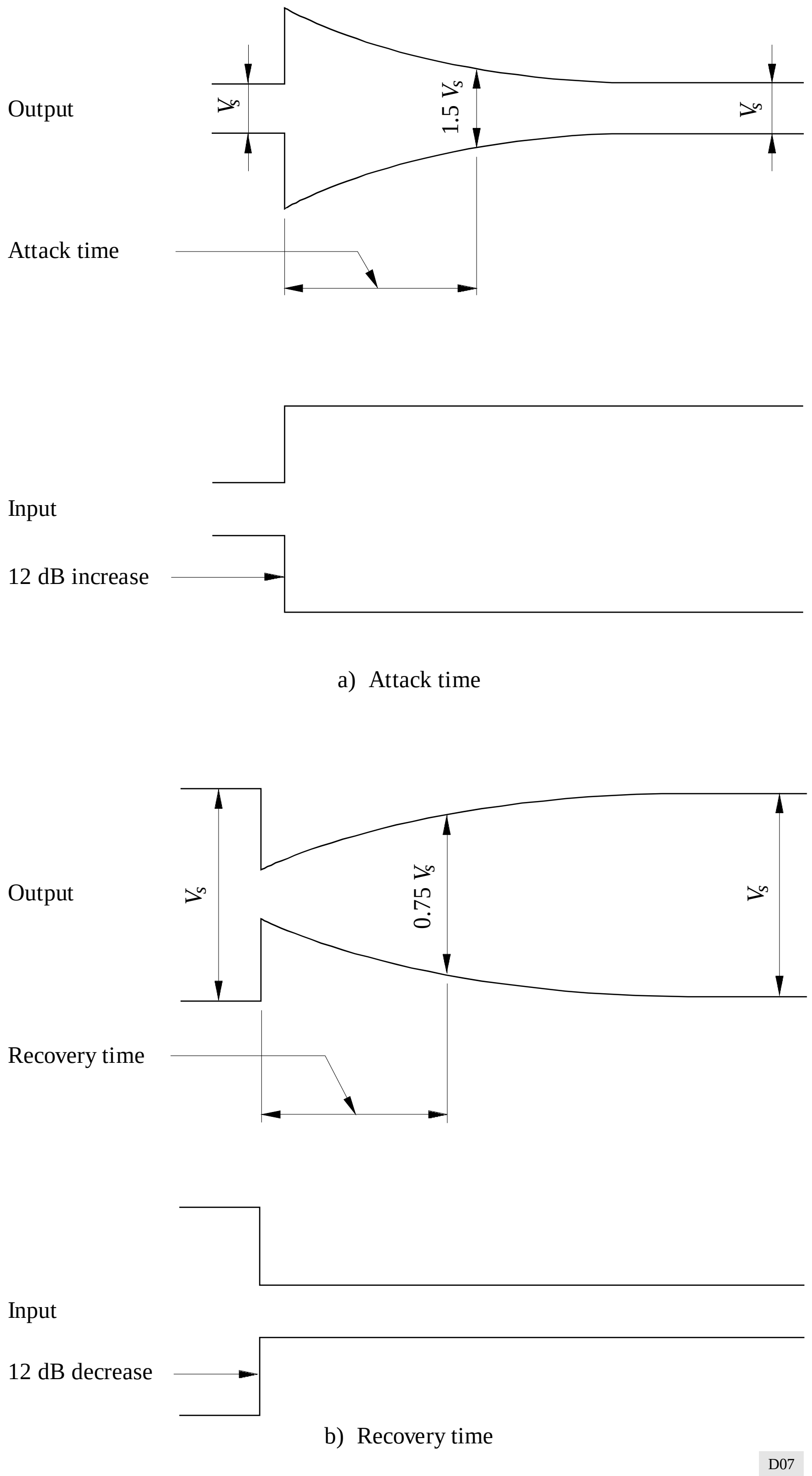
Attack time: (Fig. 7a))	11 ± 2 ms
Recovery time: (Fig. 7b))	32 ± 6 ms

5.3.1.3 Expander (controlled by the discriminator output)

Effective dynamic range (dB)	60 dB

FIGURE 7

Transient response of fading regulator



5.3.2 Control channel

5.3.2.1 Amplitude/frequency and differential-delay characteristics of filter

Attenuation within the band (nominal centre frequency ± 90 Hz) relative to that at nominal centre frequency. (Nominal centre frequencies are defined in § 5.2.2.)	–1 to + 2 dB
Differential delay within the band (nominal centre frequency –60 to + 0 Hz)	< 3 ms
Attenuation outside the band (nominal centre frequency –200 to + 250 Hz) relative to that at nominal centre frequency	> 55 dB

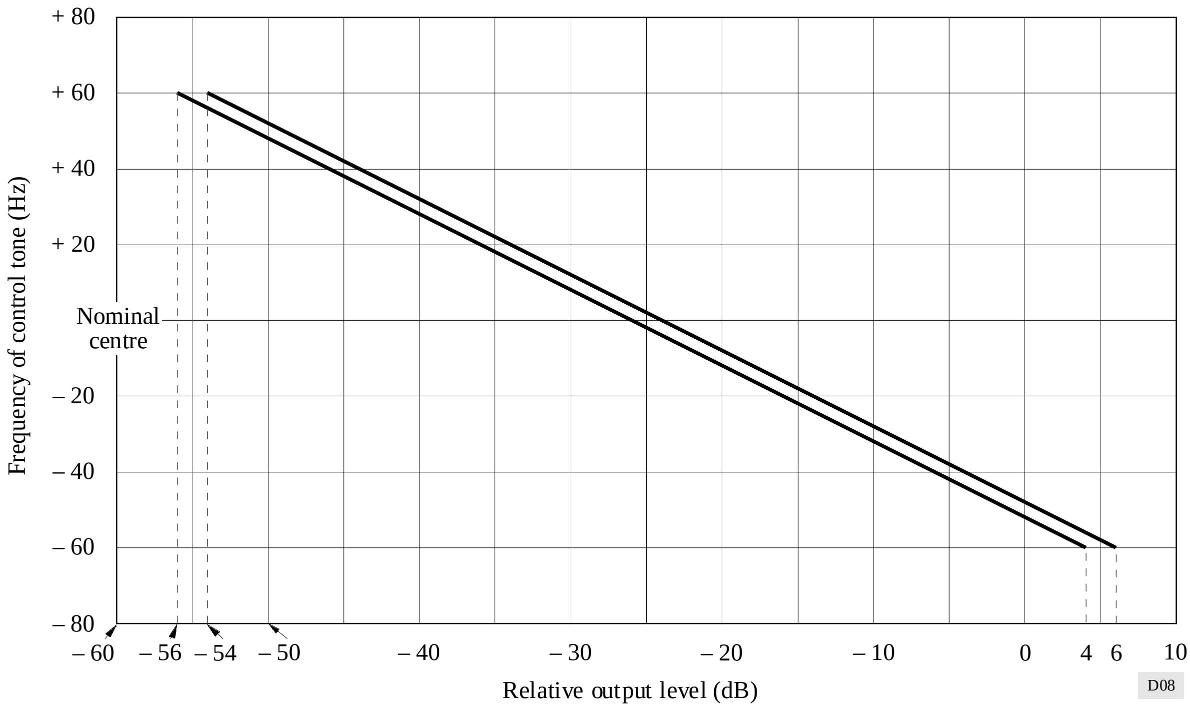
5.3.2.2 Discriminator (Frequency/amplitude translator)

Characteristic at nominal control tone level.

Changes in the expander output with changes in the frequency of the control tone should lie within the limits shown in Fig. 8.

FIGURE 8

Variation in output level at the receiver side with change in frequency of the control tone



5.3.2.3 Amplitude range of discriminator

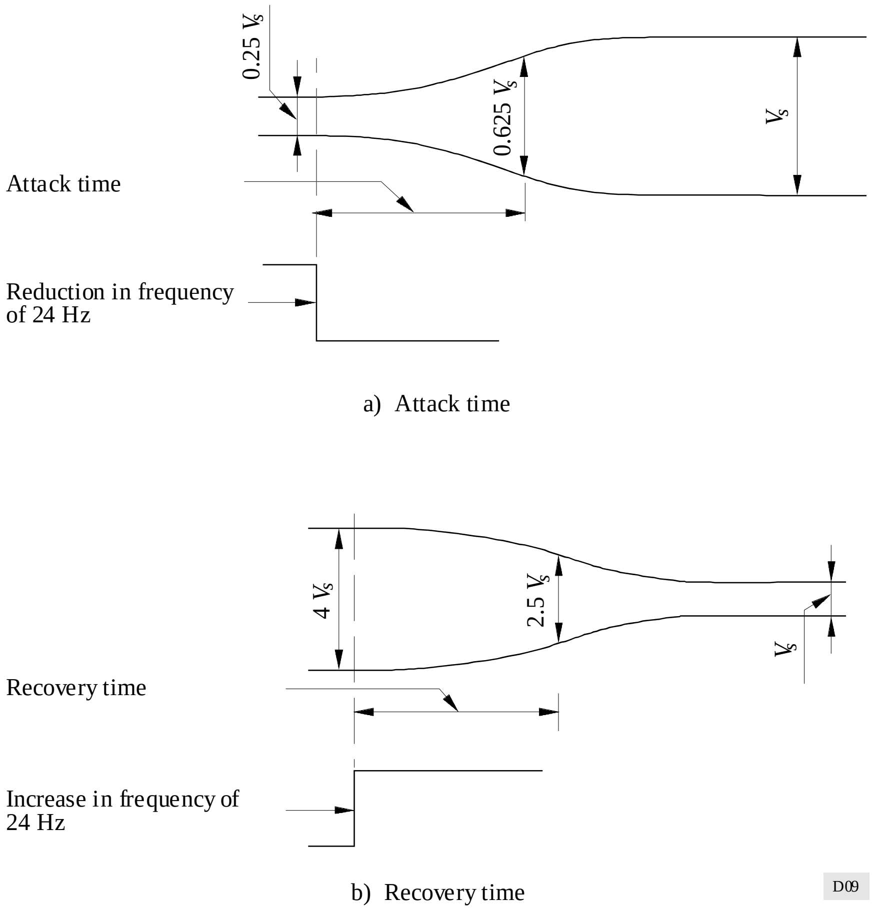
The performance quoted in § 5.3.2.2 should be met for control tone input signal levels to the discriminators from 0 dB to –30 dB relative to the nominal input level; with control tone input levels between –30 dB and –50 dB relative to nominal, an additional tolerance of ± 1 dB could be added to the limits shown in Fig. 8. For transmission systems with discrete distortion products in the control tone band further reduced operation between –30 dB and –50 dB may be allowed.

5.3.3 **Overall attack and recovery time** (a sudden change of 24 Hz in the frequency of the control tone is used to simulate a 12 dB step)

Attack time: (Fig. 9a))	20 ± 5 ms
Recovery time: (Fig. 9b))	20 ± 5 ms

FIGURE 9

Transient response of receive side



5.3.4 Frequency calibrate

When enabled, the calibrate detector shall detect the calibrate format defined by § 5.2.3. The measurement of frequency error shall be used to frequency shift the entire baseband in a direction to correct the error.

The first 20 ms of the format is for receiver and transmitter settling and not for calibrate detection.

The middle 256 ms of the format should be used for calibrate detection.

The last 20 ms of the format is used to determine the received control tone frequency. This presupposes a positive calibrate detection. Frequency error is defined as the algebraic difference of the measured received control tone frequency and the transmitted (known) nominal centre control tone frequency.

Minimum error to be detected and corrected	± 80 Hz
Minimum error design goal	± 100 Hz
Maximum post-correction baseband error	± 2 Hz

5.3.5 Receive modes

For operation enhancement and for interoperability with non-Lincompex stations, the following selectable receive modes are defined:

– *Automatic silence:* The demodulator shall maintain silence except in the presence of a received Lincompex signal. Frequency calibrate shall be selectable.

– *Automatic bypass:* The demodulator shall ascertain the presence and absence of usable Lincompex signals (see Note 1). A usable Lincompex signal is defined as one which upon demodulation provides aural advantages to the listener. If a usable signal is present, Lincompex demodulation shall proceed. If a usable signal is not present, the fading regulator and expander shall be made linear. Speech filters shall remain in place. Frequency calibrate shall be selectable.

  NOTE 1 – This determination is subjective but also objective in that enhanced low *S*/*N* operation depends on demodulation design techniques. Experience shows that adequate demodulation is possible for voice channel *S*/*N* in the 0 dB to + 10 dB range.

– *Bypass:* The fading regulator and expander are made linear. Speech filters remain in place. Frequency calibrate is selectable.

– *Wideband:* Same as bypass except that the speech bandwidth is 150 Hz to 3 400 Hz within 2 dB. Speech filters are bypassed. Frequency calibrate is selectable.

5.4 Equalization (overall) of transmission time

To ensure a reasonable transmission standard, in particular of tone pulses, such as would be used for ringing or signalling, the overall transmission times of the speech and control channels should be equalized at the input to the expander to within 4 ms.

To ensure that this can be achieved with independent designs of equipment, the time equalization provided should be divided equally between the transmit and receive sides of the equipment.

5.5 Ringing and dialling

Care should be taken to ensure that ringing and dialling signals are either passed completely through the equipment at both ends or completely by-pass both ends. The first method is to be preferred.

5.6 Data

Although not optimized for data the system will provide some advantages. If full Lincompex is selected and a transmit data signal is not present, the input to the receive end data demodulator will be held quiet. When wideband mode is selected the system passes linearly the band 150 Hz to 3 400 Hz so the voice filters are not utilized which may adversely affect data integrity. The frequency calibrate can be used to eliminate frequency error from data signals. Each administration should determine system applicability for the particular data application.

5.7 Transmission path linearity

The compressed nature of the Lincompex signal has a peak-to-mean ratio of about 8 dB with the possibility of transient peaks at the compressor output; then adequate linearity margin should be allowed in the transmission equipment between the Lincompex transmit terminals and the transmitter. Similar considerations apply to equipment between the radio receiver output and the Lincompex receive terminals.

Receivers to be used must also provide signal levels with adequate linearity margins.

5.8 Frequency stability

The maximum allowable end-to-end frequency error of each Lincompex channel should be within ± 2 Hz, which is $\pm 3 \times 10^{-8}$ per end assuming equal equipment on both ends operating at 30 MHz. This requires crystal oven oscillators. The frequency calibrate described herein allows an end-to-end frequency error of ± 80 Hz, or $\pm 1.3 \times 10^{-6}$ per end, does not require crystal oven oscillators and will accommodate most radio equipment.

NOTE 1 – For definition of signal-to-test level ratio (dBm0) see the relevant ITU-T texts.

NOTE 2 – The definitions of attack time and recovery time which are similar to those defined by the ITU-T for compandors (ITU-T Recommendation G.162), are as follows:

– the attack time of a compressor is defined as the time between the instant when a sudden increase of 12 dB in input is applied and the instant when the output voltage envelope reaches a value equal to 1.5 times its steady-state value;

– the recovery time of a compressor is defined as the time between the instant when a sudden decrease of 12 dB in input is applied and the instant when the output voltage envelope reaches a value equal to 0.75 times its steady-state value.

NOTE 3 – The parameters listed above are considered to be the minimum that should be agreed if compatibility between equipment is to be ensured. In addition, maximum tolerances have been quoted, but it has been assumed that these will not be used as design limits.

NOTE 4 – The temperature and power source variations with time, over which the parameters should be maintained, will vary between administrations and have not therefore been included. The ITU-T, however, in their specification for compandors (ITU-T Recommendation G.162), state that the performance should be maintained over a temperature range of +10 °C to +40 °C and with power source variations of ±5% of nominal; but 0 °C to +50 °C and ± 10% variations are the preferred design minimum.

NOTE 5 – Additional parameters which would normally be included in a specification for this class of equipment, i.e., input and output impedances and levels, signal-to-noise ratio, harmonic distortion, etc., have not been included as their value is not considered essential to compatibility between equipments. Administrations will wish to add their own values to ensure the satisfactory integration of the equipment into their own networks, in particular the selection of control tone frequency and applicability of the system to data signals.

NOTE 6 – The type of transmission in the control channel according to this Recommendation is not considered as class of emission F3E; therefore any provision of the Radio Regulations according to which class emission F3E is prohibited for the fixed services in the bands below 30 MHz does not apply.