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First supplement: Appendices
Second supplement: Unwanted modulation, including hum and noise modulation

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Troisième partie: Modulation utile et modulation parasite
Premier complément: Annexes
Deuxième complément: Modulation parasite

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Part 3: Wanted and unwanted modulation

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

METHODS OF MEASUREMENT FOR RADIO TRANSMITTERS

Part 3 : Wanted and unwanted modulation

FOREWORD

1) The formal decisions or agreements of the IEC on technical matters, prepared by Technical Committees on which all the National Committees having a special interest therein are represented, express, as nearly as possible, an international consensus of opinion on the subjects dealt with.
2) They have the form of recommendations for international use and they are accepted by the National Committees in that sense.
3) In order to promote this international unification, the IEC expresses the wish that all National Committees having as yet no national rules, when preparing such rules, should use the IEC recommendations as the fundamental basis for these rules in so far as national conditions will permit.
4) The desirability is recognized of extending international agreement on these matters through an endeavour to harmonize national standardization rules with these recommendations in so far as national conditions will permit. The National Committees pledge their influence towards that end.

PREFACE

This Recommendation has been prepared by Sub-Committee 12C, Radio Transmitting Equipment, of IEC Technical Committee No. 12, Radio-communication.

Several drafts were discussed at meetings held in London and in Kootwijk in 1964, in Constanz and in Paris in 1965, in Lidingö in 1966 and in Prague in 1967. As a result of this latter meeting, final drafts of the various sections were submitted to the National Committees for approval under the Six Months' Rule in February and April 1970.

The following countries voted explicitly in favour of publication of this Recommendation :

Australia
Belgium
Czechoslovakia
Denmark
France
Germany
Hungary
Iran
Israel
Italy
Japan
Korea (Democratic People's Republic of)
Netherlands
Sweden
Switzerland
Turkey
Union of Soviet Socialist Republics
United Kingdom
United States of America

METHODS OF MEASUREMENT FOR RADIO TRANSMITTERS

Part 3 : Wanted and unwanted modulation

INTRODUCTION

This Recommendation forms Part 3 of a Recommendation which, when completed, will describe recommended methods of measurement for radio transmitters for various classes of emission.

Part 3, the present edition of which is still incomplete, describes the conditions and methods of measurement for assessing the performance of transmitters with respect to wanted and unwanted modulation. Information of a general character and Recommendations and Reports of the International Telegraph and Telephone Consultative Committee (C.C.I.T.T.) and International Radio Consultative Committee (C.C.I.R.) published by the International Telecommunication Union (I.T.U.) have been added in whole or in part in the Appendices of this Recommendation, when it was considered necessary to have these references at hand. These Appendices are contained in the first Supplement to Part 3 (IEC Publication 244-3A).

In due course, Part 3 will be supplemented with Section Five : Unwanted modulation, including hum and noise modulation, which is still under consideration.

Where references are made in Part 3 to other parts of the complete Recommendation (IEC Publication 244), these references concern the following Publications :

Publication 244-1 : (First edition, 1968)	Part 1 : General Conditions of Measurement, Frequency, Output Power and Power Consumption.
Publication 244-1A (First edition, 1968)	First Supplement to Publication 244-1 (1968) — Appendices.
Publication 244-2 : (First edition, 1969)	Part 2 : Bandwidth, Out-of-band Power and Power of Non-essential Oscillations.
Publication 244-2A : (First edition, 1969)	First Supplement to Publication 244-2 (1969) — Appendices.
Publication 244-2B : (First edition, 1969)	Second Supplement to Publication 244-2 (1969) — Modulating Signals for the Measurement of Bandwidth and Out-of-band Power of Transmitters for Telephony and Sound Broadcasting.
Publication 244-5 : (First edition, 1971)	Part 5 : Measurements Particular to Transmitters and Transposers for Monochrome and Colour Television.
Publication 244-5A : (First edition, 1971)	First Supplement to Publication 244-5 (1971) — Appendices.

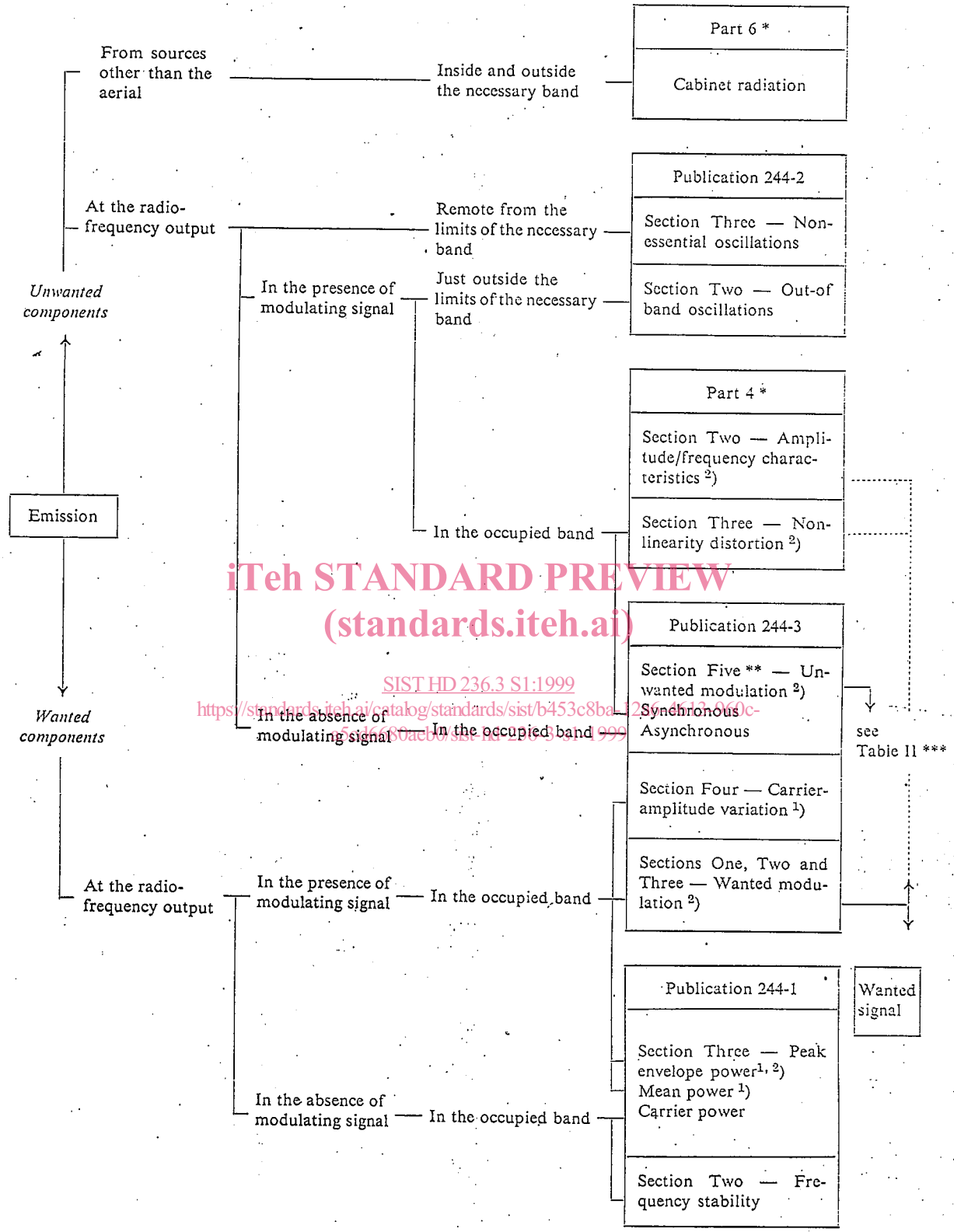
In due course, the Recommendation will be supplemented with the following parts which are still under consideration :

Part 4 : Amplitude/Frequency Characteristics and Non-linearity Distortion in Transmitters for Radiotelephony and Sound Broadcasting ;

Part 6 : Cabinet Radiation and Terminal Interference Voltages.

The relation between this part and the other parts of the Recommendation is shown in the Table on page 9.

TABLE SHOWING THE RELATION BETWEEN THE VARIOUS PARTS OF IEC PUBLICATION 244



1) Amplitude-modulation transmitters only.
2) For transmitters for monochrome and colour television, see IEC Publication 244-5.
* Under consideration.
** Section Five, which is still under consideration, will be published separately.
*** Contained in Section Five.

1. Object

This Recommendation is intended to standardize the conditions and methods of measurement to be used to ascertain the performance of a radio transmitter and to make possible the comparison of the results of measurements made by different observers.

This Recommendation contains details of selected methods of making measurements for assessing the essential properties of a radio transmitter. The methods of measurement described are restricted to those properties that may be liable to ambiguous interpretation due to the application of different methods and conditions of measurement. They are neither mandatory nor limiting ; a choice of measurements can be made in each particular case. If necessary, additional measurements may be performed, but these shall preferably be carried out in accordance with standards laid down by other IEC Technical Committees or Sub-Committees, or by other international bodies.

Limiting values of the various quantities for acceptable performance are not specified as these should be given in the relevant equipment specification, preferably in the form laid down in a forthcoming IEC Recommendation.

The methods of measurement detailed in this Recommendation are intended for type tests, but may also be used for acceptance tests and factory tests ; see Clause 3 of IEC Publication 244-1.

2. Scope

This Part 3, which should be used in conjunction with IEC Publication 244-1 and, if applicable, with other parts of IEC Publication 244, describes the conditions and methods of measurement for assessing the performance with respect to wanted and unwanted modulation.

The methods, specified in this Part 3, apply to transmitters for various classes of emission, except television transmitters and transmitters used in radio-relay systems and radio determination systems.

For transmitters for monochrome and colour television, reference is made to Section Seven of IEC Publication 244-5.

For transmitters used in radio-relay systems, reference is made to a separate IEC Publication which is still under consideration.

SECTION ONE — GENERAL TERMS RELATING TO WANTED MODULATION

3. General notes on modulation

With respect to the subject dealt with in this Recommendation, it is considered useful to draw attention to the following.

3.1 *Classification of emissions*

Emissions may be distinguished by (1) the characteristics of the basic signal conveying the information, (2) the type of signal modulating the main carrier, or (3) the type of modulation and (4) the characteristics of this carrier.

As to :

1) The basic signal which is originally formed to represent a simple sequence of information in analogue or quantized form, a large number of types exist, from a single sinusoidal voltage, to complex oscillations with a broad frequency spectrum commencing at zero frequency, for instance, the transmission of television signals.

Furthermore, distinction has to be made with respect to :

2) The type of the oscillation modulating the main carrier, e.g. a main carrier modulated either directly with the basic signal, or with the oscillation resulting from one or more, sinusoidal or pulsed, sub-carriers modulated by one or more basic signals.

3) The type of the final modulating process of the main carrier : amplitude modulation, frequency modulation or phase modulation.

4) The characteristics of the main carrier, e.g. the relative amplitude (full, reduced or suppressed) of the carrier of amplitude-modulated emissions.

A brief survey of the characteristics of interest is given in Appendix B dealing with the method of classification of emissions recommended by the C.C.I.R.

Note. — In this Recommendation, however, the abbreviations according to the method of classification given in the Radio Regulations, Geneva 1968, and reproduced in Appendix B of IEC Publication 244-1A, are used for the time being.

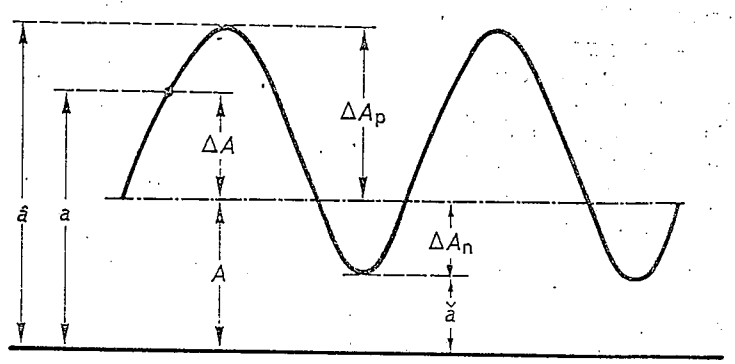
The object of Section One of this Recommendation is to define, for the variety of classes of emission just mentioned, the quantities which characterize the condition of a radio-frequency oscillation modulated with a given periodic signal.

In the following sub-clauses, a brief explanation is given of the basic concepts. A more exact description of the various terms is given in Clauses 4 and onwards of this section. The corresponding methods of measurement are contained in Section Two of this Recommendation.

3.2 *Modulated value deviation*

By the process of modulation, one of the characteristic quantities — amplitude, frequency or phase — of a radio-frequency oscillation is modified, as a result of which the instantaneous value a of the modulated quantity varies as a function of time ; see Figure 1.

The difference ΔA between the instantaneous value and a specific "characteristic value" A of this quantity, will be described by the general term "modulated value deviation". The characteristic value A depends on the class of emission and will be further explained in the following sub-clauses.



a = instantaneous value of modulated quantity
$\hat{a}, \check{a}$ = maximum, minimum peak value of a
ΔA = $a - A$ = modulated value deviation
A = level corresponding to the characteristic value of a for which $\Delta A = 0$
$\Delta A_p, \Delta A_n$ = positive, negative peak deviation

FIG. 1. — Instantaneous value of modulated quantity as a function of time.

In contrast to the modulation factor, the concept of utilization factor, the practical application of which is further explained in the following clauses of this section, may be used for transmitters for all classes of emission, irrespective of the basic quantity which is being varied during the modulation process and irrespective of its waveform. It particularly applies to transmitters for amplitude-modulated emissions, the carrier of which is reduced or suppressed.

4. Amplitude-modulated emissions

4.1 *Application*

The terms explained in this clause do not apply to telegraphy and facsimile with direct modulation (on-off keying) of the main carrier and to vestigial-sideband television.

If an asterisk (*) is added to the symbol indicating a certain class of emission, the contents of the relevant sub-clause applies only to the oscillation resulting from the modulation of the main carrier with an unmodulated sub-carrier.

4.2 *Carrier amplitude*

a) Carrier amplitude in the absence of modulation

The term is self-explanatory.

Dependent on the relative amplitude of the unmodulated carrier, amplitude-modulated emissions may be classified as follows :

1) *Full carrier emissions :*

— *Continuous emission*, modulated in amplitude by one or more sinusoidal oscillations of fixed frequency and amplitude (A2, A2H).
— *Telegraphy* (A2*).
— *Telephony* (A3, A3H).
— *Facsimile* (A4*), two-condition (black and white) and half-tone (phototelegraphy).

2) *Reduced carrier emissions :*

— *Telephony* (A3A, A3B).
— *Facsimile* (A4A*), two-condition.
— *Multi-channel voice-frequency telegraphy* (A7A, A7B, A9B).

3) *Suppressed carrier emissions :*

— *Telephony* (A3J).
— *Multi-channel voice-frequency telegraphy* (A7J).

Note. — For the meaning of the terms full, reduced and suppressed carrier, reference is made to Appendix C of IEC Publication 244-1A.

b) Carrier amplitude during modulation

The carrier amplitude of an oscillation, amplitude-modulated with a given periodic signal, is the amplitude of that component in the spectrum of the oscillation, which corresponds to the position of the carrier.

For practical reasons and to facilitate the measurements on transmitters for double-sideband emissions with full carrier, the arithmetic mean of the instantaneous amplitude during one cycle of modulation is considered as a measure of the carrier amplitude during modulation. In this last case, the deflection of a moving coil instrument connected to the d.c. output terminals of a linear envelope detector is a measure of the carrier amplitude.

Due to distortion occurring during the process of modulation or due to other causes, the carrier amplitude during modulation generally differs from the carrier amplitude in the absence of modulation ; its relative change is treated in Sub-clause 4.3.

4.3 *Carrier-amplitude variation*

4.3.1 *Definition*

The *carrier-amplitude variation* of an oscillation, amplitude-modulated with a given periodic signal, is the ratio of the difference between the *carrier amplitude during modulation* and the *carrier amplitude in the absence of modulation* to the latter.

4.3.2 *Application*

The term carrier-amplitude variation applies to the classes of emission with full carrier and with reduced carrier mentioned in Items 1) and 2) of Sub-clause 4.2.

Note. — The equivalent term "carrier-amplitude shift" is sometimes used in connection with amplitude-modulation transmitters with full carrier, and the term "carrier compression" when the carrier is reduced; see also Clause 14.

4.3.3 *Methods of measurement*

See Clauses 15 and 16 for emissions with full carrier and with reduced carrier, respectively.

4.4 *Amplitude deviation and maximum usable amplitude deviation*

4.4.1 *Introduction*

The amplitude deviation and the maximum usable amplitude deviation as such are hardly ever specified or determined. The terms are explained for the purpose of defining the relative deviation, i.e. the modulation factor and the utilization factor.

The "characteristic value" of the instantaneous amplitude of the modulated oscillation as mentioned in Sub-clause 3.2, is, for the classes of emission considered here, equal to the carrier amplitude during modulation.

4.4.2 *Definitions*

a) The positive (or negative) *amplitude deviation* of an oscillation, amplitude-modulated with a given periodic signal, is the difference between the maximum (or minimum) amplitude of the oscillation and the *amplitude of the carrier during modulation*.

b) The *maximum usable amplitude deviation* in an amplitude-modulation transmitter is the value to which the *amplitude deviation* under normal operating conditions is limited on account of technical and/or operational requirements.

4.4.3 *Application*

The terms amplitude deviation and maximum usable deviation apply to the classes of emission mentioned in Sub-clause 4.2, as follows :

1) *Full carrier emissions*

On account of either the permissible non-linearity distortion (e.g. the harmonic distortion at a given modulating frequency ; see IEC Publication 244-4 (under consideration)), the permissible out-of-band radiation (see IEC Publication 244-2), or design considerations related to the reliability of the equipment, it may be necessary to limit the amplitude deviation under normal operating conditions to a maximum usable value equal to, or smaller than the amplitude of the carrier.

2) *Reduced carrier emissions*

Under normal operating conditions, the positive amplitude deviation is to be limited to a maximum value determined by one of the factors mentioned in Item 1).

Instead of the harmonic distortion, the intermodulation distortion (see IEC Publication 244-4 (under consideration)) is mostly used as a measure of the permissible non-linearity distortion.

3) *Suppressed carrier emissions*

When the carrier is suppressed, the negative amplitude deviation is zero and the positive amplitude deviation equal to the maximum amplitude of the radio-frequency oscillation during modulation.

With respect to the maximum usable amplitude deviation, the considerations mentioned in Item 2) apply.

It should be noted that when a transmitter is modulated with an arbitrary signal to a level such that, at the output, the positive amplitude deviation is equal to the maximum usable amplitude deviation, the transmitter is delivering its maximum (or rated) peak envelope power (defined in Clauses 18 and 20 of IEC Publication 244-1) to its terminal load.

4.5 *Utilization factor*

4.5.1 *Introduction*

The reference value of the modulated value deviation mentioned in the general definition of utilization factor in Sub-clause 3.4 is, for the classes of emission considered here, equal to the maximum usable amplitude deviation.

4.5.2 *Definition*

The *utilization factor* of an amplitude-modulation transmitter producing an oscillation with a given periodic modulation-envelope is the ratio, usually expressed in per cent or decibels, of the *amplitude deviation* of the modulated oscillation to the *maximum usable amplitude deviation*.

4.5.3 *Application*

Although the concept of utilization factor may be applied to transmitters for all classes of amplitude-modulated emissions mentioned in Sub-clause 4.2, it is generally used in connection with transmitters for single-sideband and independent-sideband emissions with reduced or suppressed carrier.

The general formula for the utilization factor u of an amplitude-modulation transmitter reads :

$$u = \frac{\Delta A}{\Delta A_{max}} \qquad (4.5.3a)$$

where :

ΔA = the amplitude deviation of the modulated oscillation
ΔA_{max} = the maximum usable amplitude deviation

If the influence of the *carrier-amplitude variation* is negligible, the utilization factor can be deduced from the envelope of the radio-frequency oscillation (see Figures 2 and 3, page 25, and Figure 4, page 27) by using the formula :

$$u = \frac{\Delta A}{\Delta A_{max}} = \frac{\hat{a} - A_o}{\hat{a}_{max} - A_o} \qquad (4.5.3b)$$

where :

$\hat{a}$ = the maximum amplitude of the modulated oscillation
$\hat{a}_{max}$ = the maximum usable value of $\hat{a}$, i.e. the amplitude corresponding to maximum (or rated) peak envelope power
A_o = the amplitude of the unmodulated carrier

The utilization factor is zero (0% or $-\infty$ dB) if $\hat{a} = A_o$, i.e. in the absence of any modulation. When the transmitter is modulated with an arbitrary signal, such that in the peaks $\hat{a} = \hat{a}_{max}$, the utilization factor is equal to unity (100% or 0 dB) and the transmitter is delivering its maximum (or rated) peak envelope power. The utilization factor can exceed unity, but under normal conditions of actual traffic this should not occur for more than a specific small percentage of the time.

If the carrier is suppressed, formula 4.5.3b is reduced to :

$$u = \frac{\hat{a}}{\hat{a}_{max}} \qquad (4.5.3c)$$

since A_o is zero ; see Figure 5, page 27.

Note. — This formula may also be used as an approximation for high values of the utilization factor of transmitters, the carrier power of which is reduced to less than −16 dB with respect to rated peak envelope power.

4.5.4 *Methods of measurement*

See Clause 8.

4.6 *Modulation factor*

4.6.1 *Definition*

The *modulation factor* of an oscillation with full carrier, amplitude-modulated with a given periodic signal, is the ratio, usually expressed in per cent, of the *amplitude deviation* to the *carrier amplitude during modulation*.

4.6.2 *Application*

In contrast to the utilization factor, the concept of modulation factor applies only to the classes of full-carrier emissions listed in Item 1) of Sub-clause 4.2.

A positive deviation ΔA_p and a negative deviation ΔA_n may be distinguished, which can be equal or unequal. The corresponding positive modulation factor m_p and negative modulation factor m_n may be calculated from the formulae :

$$m_p = \frac{\Delta A_p}{A_o'} \quad \text{and} \quad m_n = \frac{\Delta A_n}{A_o'} \qquad (4.6.2a)$$

where :

A_o' = the amplitude of the carrier during modulation

If the influence of the *carrier-amplitude variation* is negligible, the modulation factor may be deduced from the envelope of the radio-frequency oscillation (see Figures 2 and 3, page 25) by using the formulae :

$$m_p = \frac{\hat{a} - A_o}{A_o} \quad \text{and} \quad m_n = \frac{A_o - \check{a}}{A_o} \qquad (4.6.2b)$$

where :

$\hat{a}$ = the maximum amplitude of the modulated oscillation
$\check{a}$ = the minimum amplitude of the modulated oscillation
A_o = the amplitude of the carrier in the absence of modulation