

REPORT ITU-R M.739-1

INTERFERENCE DUE TO INTERMODULATION PRODUCTS IN THE
LAND MOBILE SERVICE BETWEEN 25 AND 1000 MHz

(Study Programme ITU-R 7C/8)

(1978-1986)

1. Introduction

Intermodulation causes a degradation to radio services when:

- unwanted emissions are generated in transmitters;
 - unwanted emissions are generated in non-linear elements external to the transmitters;
- or
- in-band intermodulation products are generated in the radio-frequency stages of receivers.

These cases occur with varying probability and varying severity. They may be reduced by equipment design or careful choice of channels, but solutions of the latter type to one case of intermodulation may increase another.

2. Transmitters

The last active stage of a transmitter is usually an amplifier. The current in this stage will be repeatedly swept from zero amplitude to a maximum and the impedance of the output active device is liable to contain a small amount of non-linearity.

If any other signal from another emission is also present at the output of this stage, the non-linearity will give rise to a number of products having frequencies with specific frequency relationships to the frequency of both the wanted and unwanted signals. These products are called intermodulation products, and their frequencies may be expressed as

$$f_i = C_1 \cdot f_1 + C_2 \cdot f_2 + \dots + C_n \cdot f_n \quad (1)$$

where the sum $|C_1| + |C_2| + \dots + |C_n|$ is the order of the product.

The odd-order intermodulation products may be relatively close in frequency to the wanted signal frequency and thus coupled via the output circuit to the antenna with minimal attenuation.

In order to be able to calculate the effects of these products, it is necessary to establish certain terms.

2.1 Coupling loss, A_c

The coupling loss, A_c , in dB, is the ratio of the power emitted from one transmitter to the power level of that emission at the output of another transmitter which may produce the unwanted intermodulation product.

Typical values for the coupling loss on a common site are of the order of 30 dB.

2.2 Intermodulation conversion loss, A_I

The intermodulation conversion loss A_I , in dB, is the ratio of power levels of the interfering signal from an external source and the intermodulation product, both measured at the output of the transmitter.

Without any special precautions, typical values for semi-conductor transmitters are to be found in the range of 5 to 20 dB and for valve transmitters, in the range of 10 to 30 dB, in respect of the 3rd order product ($2f_1 - f_2$).

The overall loss between a transmitter providing the unwanted emission giving rise to the intermodulation product and a receiver operating at the frequency of the product is:

$$A = A_c + A_I + A_p \quad (2)$$

where A_p , in dB, is the propagation loss of the intermodulation product between the relevant transmitter output and the receiver input.

* This Report should be brought to the attention of Study Group 1.

Note that the power level of the transmitter in which the intermodulation is produced is not included in the formula but this level may have an effect on the value of the intermodulation conversion loss A_I .

Example

Signal frequency of transmitter producing intermodulation product:	f_1
Signal frequency of transmitter whose emission is coupled into transmitter (f_2):	f_2
Power level of transmitter (f_2):	+ 10 dBW
Assumed coupling loss A_c :	30 dB
Assumed conversion loss A_I :	15 dB
Assumed receiver threshold signal level:	-150 dBW
Overall path loss is equal to 10 dBW - (-150 dBW) = 160 dB.	
If $A_c + A_I = 45$ dB, then the required value of A_p is 115 dB.	

Figure 1 gives an example of propagation path losses at 100 MHz and, under free space conditions, a very large distance is required between the "product producing" transmitter and the receiver. If the receiver is a mobile station, this distance is considerably reduced. It may be concluded therefore that 2-frequency operation provides better conditions for the reduction of the effects of inter-transmitter intermodulation if the base receive frequency band is remote from the transmit frequency band.

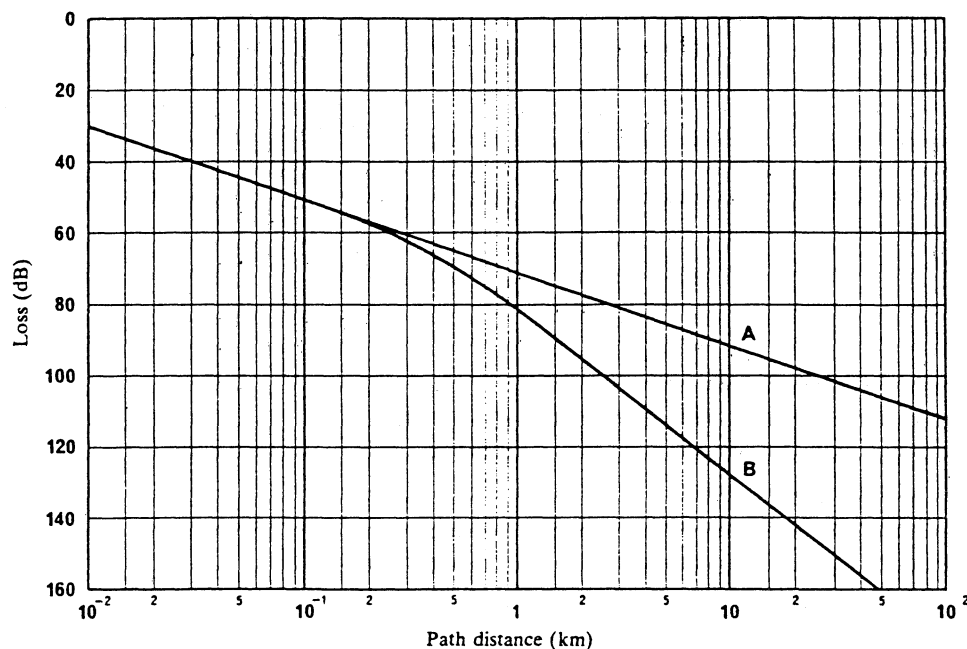


FIGURE 1 – Short range path loss at 100 MHz ($\frac{\lambda}{2}$ dipoles assumed)

Curves A: free space

B: Recommendation 370-3; $h_1 = 37.5$ m. $h_2 = 2$ m

The intermodulation caused by two or more mobile transmitters will be worse when the mobiles are closest together and when the desired signal originates at a mobile at the edge of the service area, an event which is associated with some (perhaps small) probability. The mobile being interfered with will be received at its base as a signal of widely varying level (due to fades and shadows) which will be independent of the IM interference. These wide and independent variations can allow the IM to reach harmful values for periods of time, even when its average value is much less than that of the signal.

3. External non-linear elements

On most sites, external non-linear elements will be at junctions in masts, feeders, and other antennas which are closely coupled to the radiating elements of nearby transmitters.

It would be useful to determine conversion losses for masts etc., of various qualities in terms of the isotropic loss between transmitters and the masts, etc. It would then be possible to establish specific values as good engineering practice.

4. Receivers

An intermodulation response is a response at the output of a receiver from an in-band signal generated in the RF stages of the receiver. This in-band signal is generated by the presence of two (or more) high-level signals in a non-linear section of the RF stages. As with transmitters, the two (or more) unwanted signals must have specific frequencies such that the intermodulation product lies within the frequency band accepted by the receiver.

This receiver characteristic is normally recorded as a single measurement with the level of the unwanted signals equal and is given as a single ratio which is:

the ratio of the level of these two equal signals
to

the apparent level of the intermodulation product at the input to the receiver.

It is possible, however, to cause a similar product level when the unwanted signals are not equal.

Figure 2 gives examples (3 theoretical and 1 measured) of the overall third order intermodulation characteristic of receivers. It shows that intermodulation may easily be a problem when one of the unwanted signals is not excessively high. Such curves can be used to calculate other intermodulation product levels when the unwanted signals do not have values equal to those plotted.

For a product with a frequency relationship of the form $(2f_1 - f_2)$, the level will be proportional to the level of the signal at frequency f_2 , but will vary as the square of the level of the signal f_1 ; i.e. the product will have an amplitude of the form $k \cdot V_1^2 \cdot V_2$, where V_1 , V_2 are the amplitudes of the signals at frequencies f_1 and f_2 respectively.

When a mobile receiver is used in a multi-channel system it will be subject to an intermodulation response due to many equally spaced high level signals. The following relationship has been suggested by the People's Republic of China to relate the maximum permissible signal level with the intermodulation response rejection ratio of the receiver [CCIR, 1982-86a]:

$$E_s + 3E_M \geq 3E_{I_{max}} + B + k(n,p)$$

where:

E_s : wanted signal level (dB) above sensitivity;

$E_{I_{max}}$: maximum interference signal level (dB) above sensitivity;

E_M : receiver's third-order intermodulation rejection ratio (dB) (for two signals);

B : RF protection ratio (dB);

$k(n,p)$: a constant dependent on the number of channels n and channel sequence p .

The derivation of this formula and the calculation of $k(n,p)$ are given in Annex I.

5. Reduction of intermodulation product levels in transmitters

5.1 Intermodulation conversion loss

It is obvious that a reduction of the non-linearity, particularly of the odd-numbered orders, will improve the overall performance and increase the value of the intermodulation conversion loss A_I .

From the example in § 2, it is evident that a considerable improvement is necessary before the relevant path loss reduces to manageable values.

5.2 Coupling loss

The coupling loss can obviously be increased by increasing the distance between the relevant transmitters but it may not always be possible to do so effectively at a particular site.

Ferrite isolators could be used in the output circuits of the transmitter in which the product is generated but present production units do not provide much more than 25 dB additional loss and the use of multiple units is inhibited by the inherent non-linearity of the isolators themselves. To suppress undesirable products, filters may be required after such isolators. These isolators are equally effective irrespective of the frequency spacing between f_1 and f_2 .