

RECOMMENDATION ITU-R SM.1446

**DEFINITION AND MEASUREMENT OF INTERMODULATION PRODUCTS
IN TRANSMITTER USING FREQUENCY, PHASE, OR
COMPLEX MODULATION TECHNIQUES**

(Question ITU-R 211/1)

(2000)

The ITU Radiocommunication Assembly,

considering

- a) that intermodulation (IM) products are part of the unwanted emissions (RR No. S1.146);
- b) that IM products are generated either in the radio transmission system itself and/or by interaction between different radiating elements at the same radio site;
- c) that the limits of spurious emissions cover only single- or multichannel IM products, and are prescribed by Appendix S3 of the RR and Recommendation ITU-R SM.329;
- d) that the limits of out-of-band emissions cover only single- or multichannel IM products, and are under study;
- e) that no limits are defined for inter-transmitter IM between different systems;
- f) that there is a rapid increase of shared radio sites, and that each site can potentially radiate passive and active IM products in an anomalous and uncontrolled way, and these will all add together at receivers;
- g) that the IM products due to amplitude-modulated radio transmitter are considered in Recommendation ITU-R SM.326;
- h) that there is a need to define methods of measurements of IM products, particularly for digital modulation techniques,

noting

- a) that Report ITU-R SM.2021 contains general principles on generation of IM products and the relevant mitigation techniques to minimize IM,

recommends

- 1** that when considering the types of mechanisms which generate IM products in the transmission system the definitions and the relevant measurement techniques for each type of IM given in Annex 1 should be used.

IM products in the transmitter

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1 Definitions of the different IM types in the transmitter

IM products are generated at non-linearities in the transmitter output amplifier, e.g. at semiconductors, klystrons, etc., and in passive devices like combiners, circulators, connectors, etc.

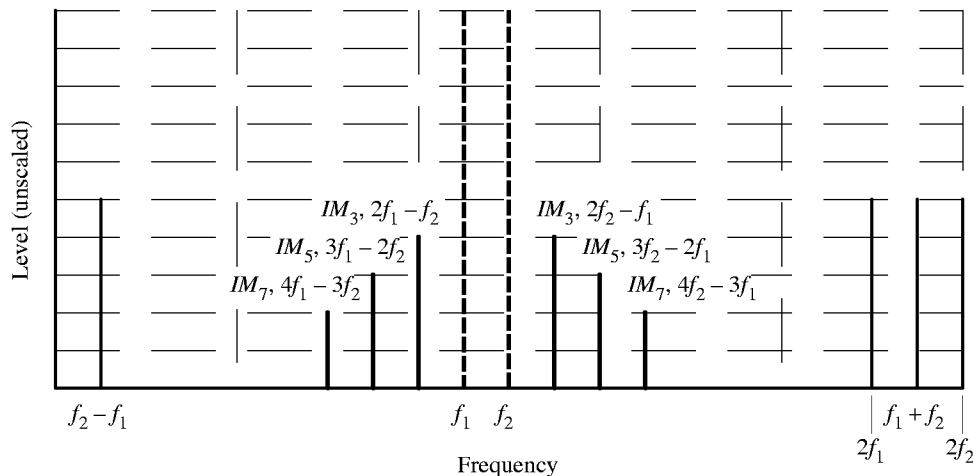
IM products at the frequency f_{IM} are generated by two or more unwanted signals at the frequencies $f_1, f_2, \dots$ at non-linearities in the output of a transmitter. The relation between f_{IM} and $f_1, f_2, \dots$ can be expressed very general:

$$f_{IM} = |m_1 f_1 + m_2 f_2 + \dots| \quad \text{with} \quad m_v = 0, \pm 1, \pm 2, \dots$$

The order of the IM product is given by $n = m_1 + m_2 + \dots$. This means that the frequency for 2nd order IM products, IM_2 with $n = 2, m_1 = m_2 = 1$ results in $f_{IM} = |f_1 \pm f_2|$ and of the 3rd order IM_3 ($n = 3, m_1 = 2, m_2 = 1$) in $f_{IM} = |2f_1 \pm f_2|$ or in $f_{IM} = |2f_2 \pm f_1|$ with $m_1 = 1, m_2 = 2$. The $2f_1 - f_2$ and $2f_2 - f_1$ products are of most concern to designers since these are often specified in standards, although the $f_1 + f_2 - f_3$ products are of greater magnitude and more numerous if there are more than two interfering signals. For some applications the 5th order IM products IM_5 occurring at $3f_1 - 2f_2$ or $3f_2 - 2f_1$, respectively, have also to be considered. The relation of the different IM products is illustrated in Fig. 1.

FIGURE 1

Unscaled IM products (bold lines) related to the fundamentals (bold dashed lines)



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Five different types of IM are defined.

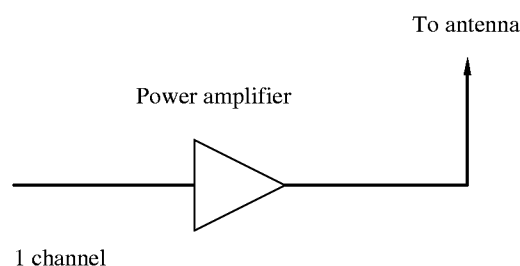
1.1 Type 1 – Single-channel IM

Single-channel IM is defined as distortion of the wanted signal by virtue of non-linearity in the transmitter circuits including all passive devices like combiners, etc.

Figure 2 illustrates this type of IM.

FIGURE 2

Type 1 – Single-channel IM

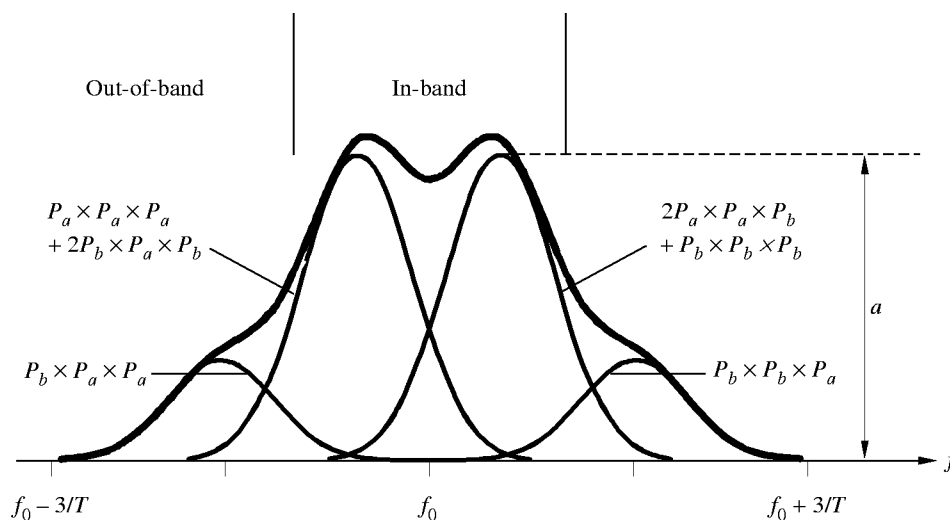


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In addition to producing IM distortion products by the mixing of two or more RF transmission signals, in-band and out-of-band emissions can be observed from a single baseband modulation signal due to mixing of discrete component frequencies of a complex transmitter input waveform. This can occur with an analogue signal such as speech which generally is comprised of several time variant frequency components. It also occurs with digital signals due to Fourier series component frequencies mixing to produce new frequency components. This leads to transmitted digital waveform distortion and an increase in the amplitude in a portion of the original signal spectrum. A truly random digital signal will contain an infinite number of these spectral components resulting in a noise-like continuous spectrum shaped by the passband filter. The effect of IM distortion is to increase the energy in sub-bands of the noise-like spectrum, especially those due to 3rd order IM. This increase in the noise-like spectrum has been referred to both as IM noise and spectral growth and often appears in digital modulation spectral plots as bumps or shoulders near the edges of the passband filter which contribute excess noise power to the adjacent band and potential interference as illustrated in Fig. 3

FIGURE 3

Example of 3rd order IM noise in the used frequency bands $BO = 0.82$ ($BI = 4.5$) and $f_0 < f < f_0 + 1/T$ where T is the symbol length, f_0 is the carrier frequency and P are the unscaled signal powers



BO : output back-off

BI : input back-off

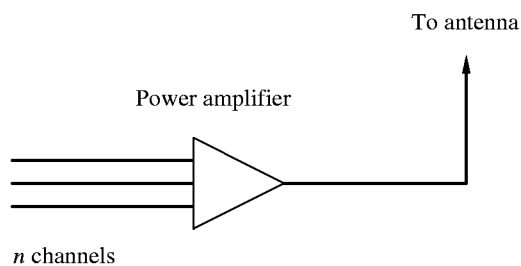
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1.2 Type 2 – Multichannel IM

Multichannel IM is defined as the situation where the wanted signals of several channels are distorted by virtue of non-linearity in the same transmitter circuits.

The signals in the different channels may have different modulations, bandwidths or different spacings within the whole band.

FIGURE 4
Type 2 – Multichannel IM



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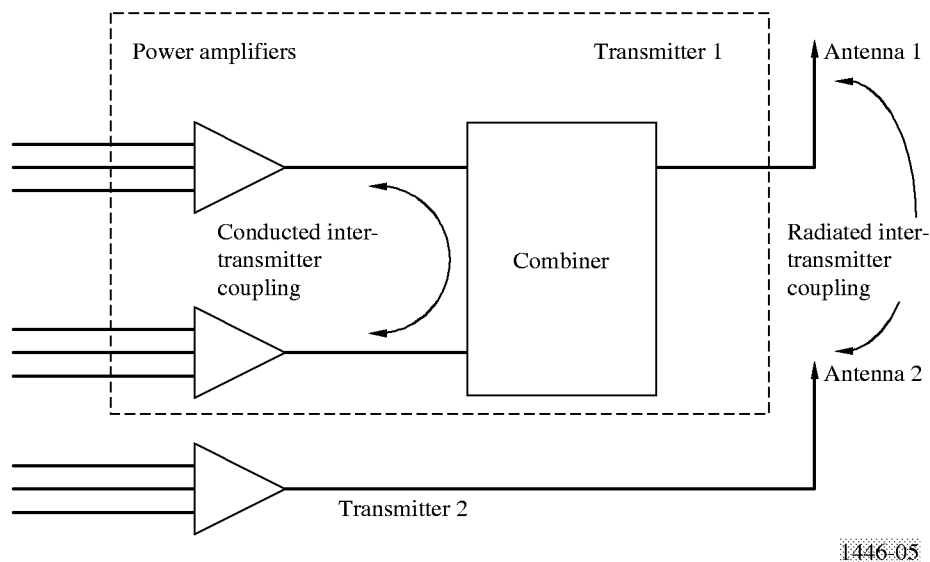
1.3 Type 3 – Inter-transmitter IM

Inter-transmitter IM, where one or more transmitters on a site intermodulate, either within the transmitters themselves, or within a non-linear component on site to produce IM products at frequencies possibly far removed from actual transmit frequencies. This is often known as the rusty bolt effect and is a function of the various problems of mainly co-site engineering, although certain tests may be called upon to be made on the transmitters themselves.

The IM products described by type 3 are induced by interfering signals entering the transmitter via its antenna. If they are near the nominal frequency of the transmitter, they may generate considerable IM products in the transmitter output. If they are far from the nominal frequency, i.e. outside the wanted operating bandwidth, the frequency selectivity of the system has also to be taken into account.

Figure 5 illustrates this type of IM.

FIGURE 5
Type 3 – Inter-transmitter IM



1.4 Type 4 – IM due to active antennas

An example of an active antenna structure used at a satellite is given in Fig. 6 for illustration.

Beam-forming upstream from power amplifiers permits the RF power losses to be limited, but imposes a multicarrier operating mode to the amplifiers: each amplifier receives all the signals to be transmitted and operates therefore on the whole system bandwidth. This distribution of the signal power over the different antenna paths permits power exchanges between the beams as well as their reconfiguration through the simple transmission of a telecommand signal.

The multicarrier operating mode of an active antenna, along with the non-linearity of amplifiers, originates spurious emissions under the form of IM signals. The analysis of these IM signals is made very complex by the active architecture of the antenna.

NOTE 1 – Active antennas are now under development and varieties of the system are now widening in the working technology and applications of communication services. These systems are envisaged to be widely used in many fields in the future, e.g. for very high-speed communication with more than 1 Gbit/s for imaging, radar, etc. Therefore, the IM from active antennas and its measurement method should be studied further.