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Exploring the Influence of Modulation Depth Variations in Undesired Signals on Receiver Interference

Habibulla Khan, Koneru Lakshmaiah Education Foundation (KLEF), Vaddeswaram 522302, Andhra Pradesh, India

Abstract

It is widely recognized that when two powerful undesired signals infiltrate a non-linear circuit at the receiver's input, they can lead to interference at the receiver's output. In the absence of the desired signal, tuning the receiver reveals both interference signals simultaneously at the output. The non-linear characteristics of specific components, such as transistors and diodes, induce frequency conversion, resulting in the emergence of frequency components that affect the receiver. The issue becomes more pronounced when the sum or difference of interference frequencies aligns with the tuning frequency, amplifying the detrimental effects. In this context, the interference signal, upon generation, undergoes a transformation, converging into an intermediate frequency (fo - Δf), alongside the desired signal. This phenomenon is depicted in Figure 1, illustrating the selectivity variation of an ideal receiver and a V-receiver. This paper delves into the mathematical analysis of the inter modulation phenomenon, aiming to discern the implications of unwanted signal modulation on interference generation. Specifically, the investigation seeks to understand how modulation depth influences the variation of unwanted signals. In conclusion, this study explores the intricate realm of interference effects within nonlinear circuits, caused by potent undesired signals. Through mathematical analysis, the research uncovers the foundations of the inter modulation phenomenon and its implications, with a particular focus on how the modulation depth of unwanted signals shapes the variation process.

Introduction

The presence of interference at the receiver output is a result of the desired signal being accompanied by amplified voltages, stemming from either undesired signals or external sources of radio interference, whether of natural or human origin. It is widely accepted that the reception quality hinges on the ratio between the desired signal and the interference signal at the receiver output. Consequently, to ensure optimal reception, a high signal-to-noise ratio is paramount [1]. In scenarios where binary signals are employed, such as digital communication systems, the quality of reception is determined by the bit error rate. The quality is particularly sensitive to interference levels. An ideal receiver boasts selectivity as depicted in Figure 1 [2]. Conversely, a practical receiver, as depicted in Figure 2, exhibits variances in selectivity. Notably, the influence of interference varies based on its frequency, as elucidated by the

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insights from Figure 2 [3]. In conclusion, the presence of interference at the receiver output is an outcome of the interaction between the desired signal and heightened voltages arising from undesired signals or external radio interference [4]. Achieving high reception quality necessitates a favorable signal-to-noise ratio. This is of paramount importance, especially in the context of binary signals where bit error rates dictate reception quality [5]. The variance in selectivity between an ideal and practical receiver further underscores the complexity of managing interference effects, with frequency standing out as a significant factor shaping the degree of influence.

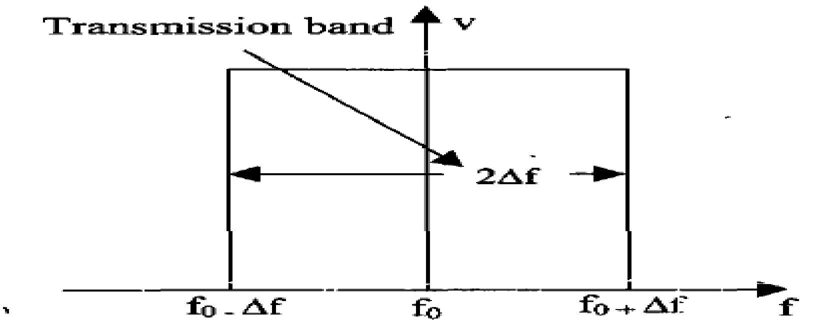

Figure 1. Selectivity variation of ideal receiver, v — receiver output voltage, f_0 — receiver tuning frequency

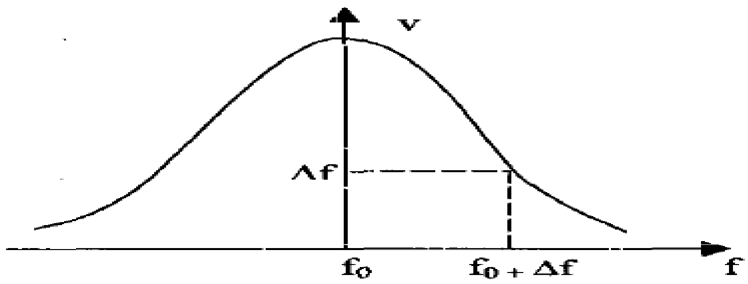

Figure 2. Selectivity variation of practical receiver

$$P_A = \frac{(E.l_{eff})^2}{4R_a} \qquad (1)$$

where E is interference field intensity of incident wave

l_{eff} is the effective antenna length

R_a is receiving antenna resistance

$$f_t = f_{i1} + f_{i2} \qquad (2)$$

or

$$f_t = f_{i1} - f_{i2} \qquad (3)$$

FORMULATIONS

A sum of the two interference voltages in the control element circuit is given by

$$v_i = v_1 \cos\omega_{i1}t + v_2 \cos\omega_{i2}t \qquad (4)$$

where v_1 and v_2 indicates the amplitudes of these voltages.
The non-linear characteristics of the amplifying element relating the output and the input is given by

$$i_{op} = g_m v_{ip} + \frac{1}{2} g_m^1 v_{ip}^2 + \ldots\ldots\ldots + \ldots. \qquad (5)$$

Here g_m is the slope of the current and voltage characteristics.

$$i_{op} = f(v_{ip}) \qquad (6)$$

$g_m^{|}$ and $g_m^{||}$ are the derivates.

From the above relations the components of sum, difference, harmonic and different combinations of frequencies are given by

$$\frac{1}{2} g_m^{|} v_1 v_2 \cos(\omega_{i1} + \omega_{i2})t$$

$$\frac{1}{2} g_m^{|} v_1 v_2 \cos(\omega_{i1} - \omega_{i2})t$$

$$\vdots$$

$$\frac{3}{24} g_m^{||} v_1 v_2^2 \cos(2\omega_{i2} + \omega_{i1})t \qquad (7)$$

The possible interference occurrences are given by

Cause	*Interference Frequency*
$g_m^{|} \neq 0$	$f_{i1} + f_{i2}$
	$f_{i1} - f_{i2}$
	$2f_{i1}$
	$2f_{i2}$
	$3\ f_{i2}$
$g_m^{||} \neq 0$	$2f_{i1} - f_{i2}$
	$2f_{i1} + f_{i2}$
	$2f_{i2} - f_{i1}$
	$2f_{i2} + f_{i1}$

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In order to obtain the analysis of cross modulation phenomenon, the following simple case is considered. Here a sum of unmodulated desired signal voltage in a non linear element of the receiver is given by

$$v_s = V_s \cos 2\pi f^1{}_s t \qquad (8)$$

and the unwanted AM signal voltage is

$$v_n = V_n\,(1 + m_n \cos 2\pi f_n t)\cos 2\pi f_s t \qquad (9)$$

where V_s and V_n are the desired signal and unwanted signal carrier wave amplitudes,

$f^1{}_s$ and f_s are the desired and unwanted signal frequencies,

m_n is modulation depth

f_n is the unwanted signal modulation frequency

Results

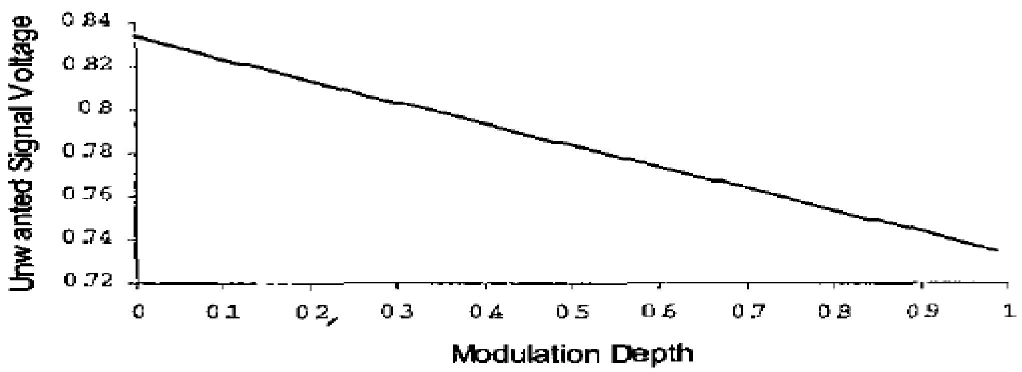

Figure 3. Variation of unwanted signal voltage with modulation depth for $f_n = 1.1$ KHz, and $f_s = 1.25$KHz

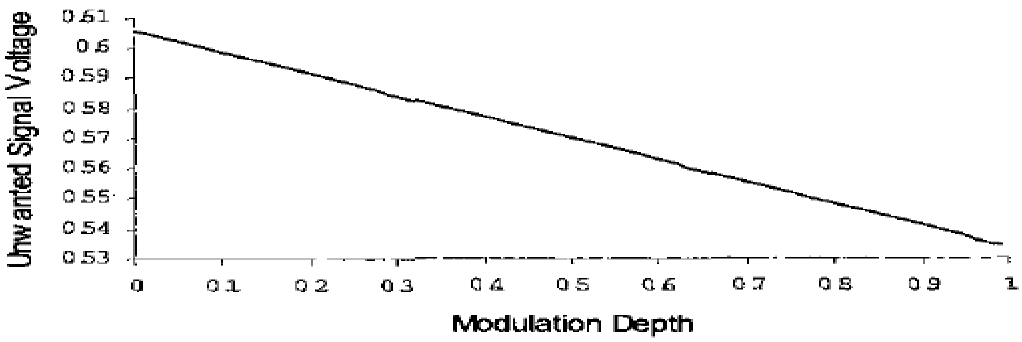

Figure 4. Variation of unwanted signal voltage with modulation depth for f_n = 1.1 KHz, and f_s = 160 KHz

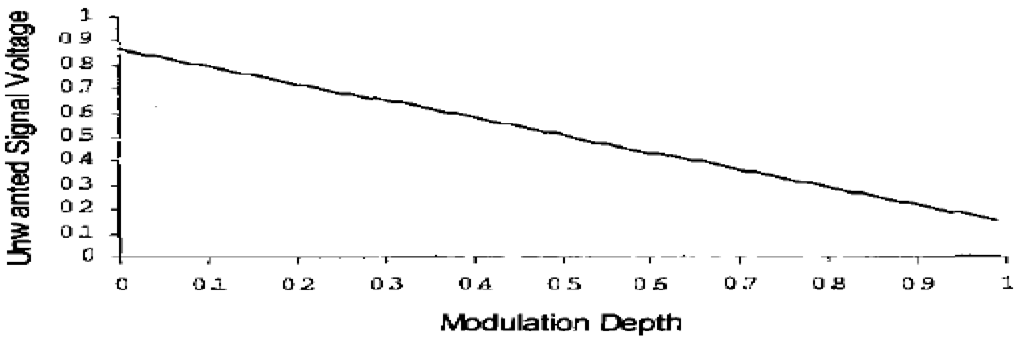

Figure 5. Variation of unwanted signal voltage with modulation depth for f_n = 1.25 KHz, and f_s = 1.45KHz

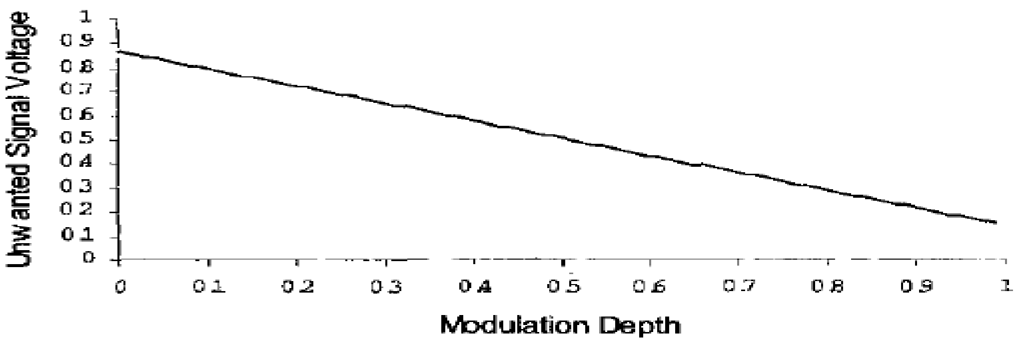

Figure 6. Variation of unwanted signal voltage with modulation depth for f_n = 1.25 KHz, and f_s = 160 KHz

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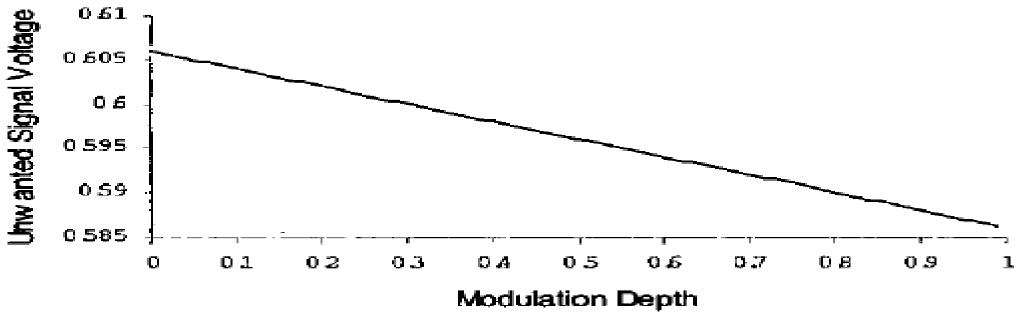

Figure 7. Variation of unwanted signal voltage with modulation depth for f_n = 1.35 KHz, and f_s = 1.5 KHz

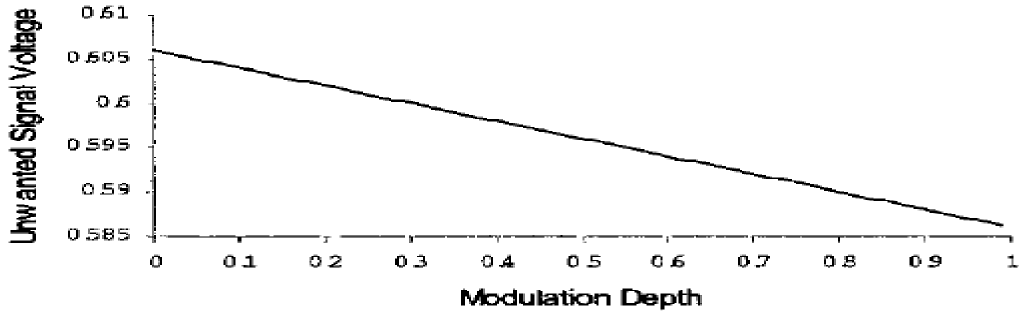

Figure 8. Variation of unwanted signal voltage with modulation depth for f_n = 1.35KHz, and f_s = 160 KHz

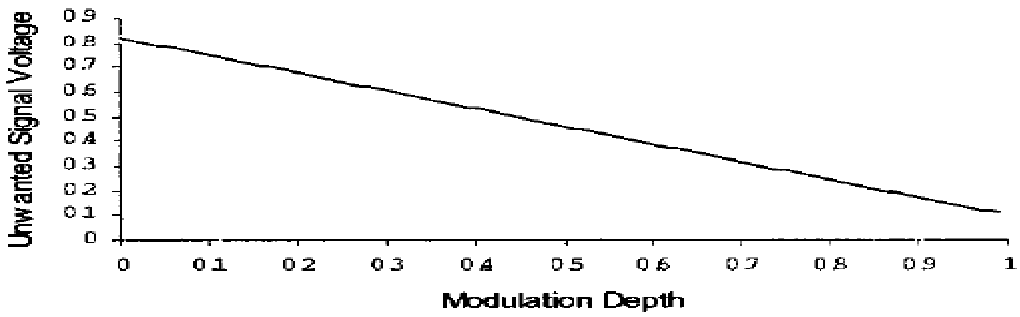

Figure 9. Variation of unwanted signal voltage with modulation depth for f_n = 1.5 KHz, and f_s = 1.65 KHz

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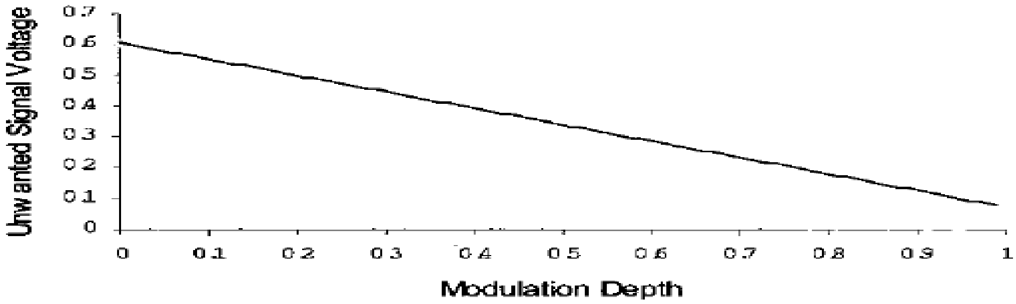

Figure 10. Variation of unwanted signal voltage with modulation depth for f_n = 1.5 KHz, and f_s = 160 KHz

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