DEUTERIUM ARRAY MEMO #008

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To: Deuterium Array Group

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Subject: Intermodulation IP2 and IP3 requirements for D1 array

1] Intermodulation

Every amplifier has a slightly non-linear transfer function. If the transfer function is expanded as a polynomial:

$$y = ax + bx^2 + cx^3 \tag{1}$$

The term bx^2 leads to the 2nd harmonic of frequencies present at the amplifier input and to the sum and difference frequencies for any 2 tones. The cx^2 term leads to third harmonics and frequencies

$$mf_0 \pm nf_1 \tag{2}$$

where the order $m + n = 3$

2] 2-tone second-order and third-order intercept points

The amplitude of second order products grow by 2 dB for every dB increase in the input tones while third order products grow by 3 dB per dB.

If a graph is made of the output power in dB vs the input power in dB the purely amplified signal has a slope of one while second and third order signals have slopes of 2 and 3 respectively. If the required limit on an unwanted product is u dB at a level of d dB for the input signals the graph of the amplified output signal y is

$$y = d + x + g \tag{3}$$

where the 2nd and 3rd order signal graphs are

$$y = u + 2x + g \quad 2^{\text{nd}} \text{ order} \tag{4}$$

and $$y = u + 3x + g \quad 3^{\text{rd}} \text{ order} \tag{5}$$

For 2nd order the graphs intersect when

$$d + x + g = u + 2x + g \tag{6}$$
$$x = d - u \tag{7}$$

so that the input IP2 incept point is

$$IP2_i = 2d - u \tag{8}$$

and the output intercept point is

$$IP2_0 = 2d - u + g = IP2_i + g \tag{9}$$

where g is the small signal gain in dB for the 3rd order the graphs intersect when

$$d + x + g = u + 3x + g \tag{10}$$
$$x = (d - u)/2 \tag{11}$$

so that

$$IP3_i = (3d - u)/2 \tag{12}$$
$$IP3_0 = (3d - u)/2 + g \tag{13}$$

3] Numerical examples

If the input signal levels are –50 dBm and the undesired intermod is at –160 dBm (1K in 8 kHz bandwidth) then

$$IP2_i = +60\,dBm$$
$$IP3_i = +5\,dBm$$

for a 25 dB amplifier

$$IP2_0 = 85\,dBm$$
$$IP3_0 = 30\,dBm$$

while the $IP3_0$ is probably easy to meet the $IP2_0$ may be a problem. Even if the potentially bothersome input signal levels are reduced from – 50 dBm to –70 dBm the $IP2_0$ requirement is still +45 dBm.

Comments

IP2 (if input or output are not specified *IP2* normally refers to the output *IP2)* is seldom specified for an amplifier since only when bandwidths are greater than 2:1 can the second order spurious signals fall within the frequency range of the desired signals. *IP2* is likely to be of most concern for systems in which there is no filter between the antenna and the first low noise amplifier. If filtering the input signals is difficult then possible methods for raising *IP2* to an acceptable level might be

1] Use of negative feedback to improve linearity.

2] Use of balanced circuit to cancel second order products.

It is not yet clear what value of IP2 will be acceptable for the D1 array. A study of the signal levels of transmissions which may produce significant intermodulation near 327.4 MHz is needed.