To: Deuterium Array Group  
From: Alan E.E. Rogers  
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:

\[ y = ax + bx^2 + cx^3 \]  

(1)

The term \( bx^2 \) leads to the 2\textsuperscript{nd} 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:

\[ mf_0 \pm nf_1 \]  

(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

\[ y = d + x + g \]  

(3)

where the 2\textsuperscript{nd} and 3\textsuperscript{rd} order signal graphs are

\[ y = u + 2x + g \text{ 2\textsuperscript{nd} order} \]  

(4)

\[ y = u + 3x + g \text{ 3\textsuperscript{rd} order} \]  

(5)
For 2\textsuperscript{nd} order the graphs intersect when

\begin{align*}
d + x + g &= u + 2x + g \\
x &= d - u
\end{align*}

so that the input IP\textsubscript{2} incept point is

\[ IP\textsubscript{2\_i} = 2d - u \]

and the output intercept point is

\[ IP\textsubscript{2\_o} = 2d - u + g = IP\textsubscript{2\_i} + g \]

where \( g \) is the small signal gain in dB for the 3\textsuperscript{rd} order the graphs intersect when

\begin{align*}
d + x + g &= u + 3x + g \\
x &= (d - u) / 2
\end{align*}

so that

\begin{align*}
IP\textsubscript{3\_i} &= (3d - u) / 2 \\
IP\textsubscript{3\_o} &= (3d - u) / 2 + g
\end{align*}

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

\begin{align*}
IP\textsubscript{2\_i} &= +60 dBm \\
IP\textsubscript{3\_i} &= +5 dBm
\end{align*}

for a 25 dB amplifier

\begin{align*}
IP\textsubscript{2\_o} &= 85 dBm \\
IP\textsubscript{3\_o} &= 30 dBm
\end{align*}

while the \( IP\textsubscript{3\_o} \) is probably easy to meet the \( IP\textsubscript{2\_o} \) may be a problem. Even if the potentially bothersome input signal levels are reduced from –50 dBm to –70 dBm the \( IP\textsubscript{2\_o} \) 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.