Using Preamps With Spectrum Analyzers

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Preamplifiers improve spectrum analyzer sensitivity by decreasing the noise figure of the pre- amplifier/analyzer combination. As preamplifier gain increases and noise figure decreases, analyzer sensitivity increases. To achieve maximum sensitivity without significantly degrading dynamic range, gain must be optimized. To determine the optimum gain, the overall system noise figure must first be evaluated, as follows:

$$F_{tot} = F_1 + (F_2 - 1)/G_1$$

F_{tot} = the total noise figure of the spectrum analyzer and preamplifier combination,
F_1 = the noise figure of the pre- amplifier
F_2 = the noise figure of the spectrum analyzer, and
G_1 = the power gain of the preamplifier.

The first criteria for the preamplifier design is clearly a preamplifier noise figure much lower than that of the spectrum analyzer. Second, the equation shows that the total noise figure decreases when G_1 increases and approaches F_1 that is, when G_1 becomes very large compared to F_2. Therefore, because the spectrum analyzer's noise level is proportional to F_2.the lowest total noise level- or best sensitivity-is obtained with the highest preamplifier gain.

However, inherent problems exist. The use of any preamplifier results in the reduction of the spectrum analyzer's dynamic range. A preamplifier with gain of G_1 reduces the input 1-dB compression point level by G_1. However, the decrease in noise level is not proportional to G_1, as shown in the equation. Therefore, there must be an optimum gain (G_1 at which the increase in sensitivity is significant without an objectionable loss of dynamic range.

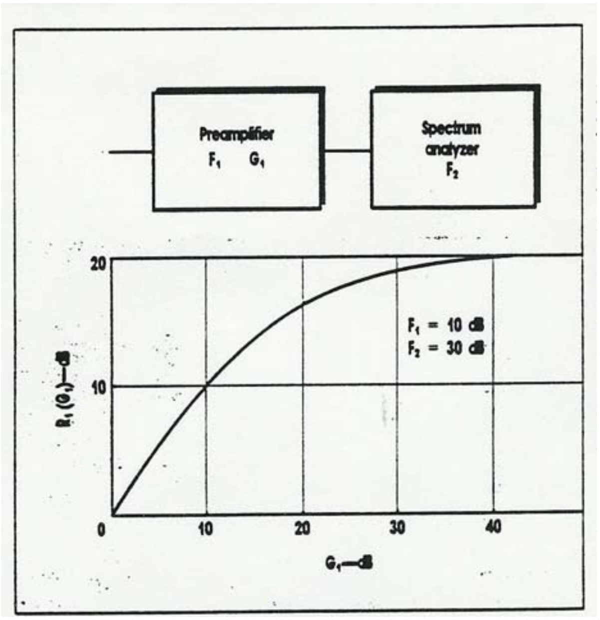

Figure 1 - Noise Level Improvement Function

A basic setup of the spectrum analyzer with an internal noise figure of F_{21} and a preamplifier with noise figure of F_1 and gain of G_1 is shown in Figure 1. The figure shows the noise-level improvement function R_1G_1 as a function of G_1 expressed in decibels, for a preamplifier with a noise figure F_1 equal to 10 dB and a spectrum analyzer with a noise figure F_2 equal to 30 dB. The preamplifier gain is variable. The ratio of the input noise of the spectrum analyzer without a preamplifier to the input noise with a preamplifier (shown in the plot) indicates the result of increasing preamplifier gain. As the gain G1 in- creases, sensitivity increases significantly until the gain reaches 20 dB. The curve indicates that gains higher than 20 dB, the sensitivity does not increase significantly.

Another function of interest is the ratio $R_1(G_1)$ of the dynamic range of the spectrum analyzer alone to the dynamic range of the spectrum analyzer with a preamplifier. Figure 2 shows a plot of the $R_1(G_1)$ in decibels, versus the preamplifier gain, G_1. The curve indicates that for gains less than 20 dB, degradation is very small. Dynamic range degradation increases rapidly (and the dynamic range decreases) as the increasing preamplifier gain,

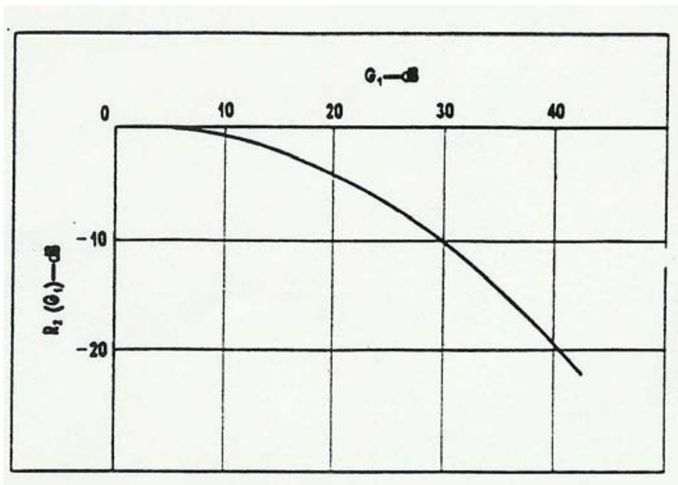

Figure 2 - Dynamic Range Degradation with Gain

Expression of Merit

The product of the two functions $R_1(G_1)$ and $R2(G_2)$ is defined as $R(G_1)$, the preamplifier's expression of merit. In essence, $R(G_1)$ is the ratio of the increase in sensitivity and the decrease in dynamic range, as a function of $G_{1.}$. When evaluating $R_1(G_1)$ and $R2(G_2)$, it is evident that the merit function $R(G_1)$ increases at low gain, indicating that the sensitivity increases without sacrificing dynamic range. However, as preamplifier gain increases, the merit function decreases. This decrease indicates that sensitivity improves only slightly, but there is a severe reduction in dynamic range.

Summary

The overall noise figure of the preamplifier/analyzer system, using the optimum preamplifier gain, is 3 dB higher than the noise figure of the preamplifier alone. In summary, when a preamplifier is used with a spectrum analyzer, its optimum gain will decrease dynamic range by only 3 dB, but will increase the sensitivity by the difference in noise figures of the spectrum analyzer and the preamplifier, minus 3 dB.