Far-Field Peak in NSI Programs

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Planar Near-Field Measurements

In the NSI 2000 Program there is a result that is referred to as "Far-Field Peak" when the far-field is computed. This quantity, which will be denoted in the following discussion as FFP, is one of the factors in the gain equation. Referring to Eq. 17b in "Gain and Power Parameter Measurements Using Planar Near-Field Techniques", IEE APS Transactions, Vol 36, No. 6, June 1988, by Newell, Ward and McFarlane, the gain is given by,

$$G_a\left(\vec{K}_0\right)=\left(\frac{4\pi}{\lambda^2}\right)^2 M\,\frac{\left|\delta_x\delta_y\sum B'_0\left(\vec{P}_j\right)e^{-i\vec{K}_0\bullet\vec{P}_j}\right|^2}{\left|a'_n\right|^2 G_p\left(\vec{K}_0\right)} \tag{1}$$

where $G_a(\vec{K}_0)$ is the gain of the antenna in the direction defined by the k-space vector $\vec{K}_0$; λ is the wavelength; M is a mismatch factor involving the complex reflection coefficients of the antenna, probe, generator and load ports; δ_x and δ_y are the data point spacings of the near field data; $B_0'\left(\vec{P}_j\right)$ is the **normalized** near-field data at the positions denoted by $\vec{P}_j$; a'_n the **normalized** input to the AUT; and $G_p\left(\vec{K}_0\right)$ is the gain of the probe. The normalization process will be discussed later. In the NSI programs, λ, δ_x and δ_y as used in the gain calculations and the calculation of the FFP, are always in meters, regardless of the units used to display these quantities in the menus.

The Far-Field Peak, is equal to the numerator of the term following the mismatch factor,

$$FFP=10\log\left[\left|\delta_x\delta_y\sum_j B_0'\left(\vec{P}_j\right)e^{-i\vec{K}_0\bullet\vec{P}_j}\right|^2\right]. \tag{2}$$

The actual magnitude of this factor will depend on how the near-field data is normalized. This can be done in various ways, but B_0' *and* a_n' **must** be normalized the same way. In the referenced APS paper both quantities are normalized to the probe output at the reference point, $b_0'\left(\vec{P}_0\right)$. This means that the normalized near-field data has a magnitude of one at the reference point and a phase of zero degrees. The reference point is arbitrary, but is usually chosen at or near the near-field amplitude peak. In the NSI processing, the measured amplitude is normalized with respect to the reference channel. The following table shows a comparison of measured values using the different normalizations.

Normalization Reference	Normalized Amplitude at reference point, $\left\|B_0'\left(\vec{P}_0\right)\right\|^2$	Normalized input to AUT, $\left\|a'_n\right\|^2$	Far-Field Peak, FFP	Ratio of Far-Field Peak to AUT Input , $\frac{\left\|\delta_x\delta_y\sum B'_0\left(\vec{P}_j\right)e^{-i\vec{K}_0\bullet\vec{P}_j}\right\|^2}{\left\|a'_n\right\|^2}$
Reference Point Amp, $\left\|b_0'\left(\vec{P}_0\right)\right\|$	0 dB	+20.64 dB	-27.64 dB	-48.28
Reference channel, a_0	-43.0 dB	-22.36 dB	-70.64 dB	-48.28

It is apparent that the final gain is the same regardless of which normalization is used.

Some physical meaning can be attached to the Far-Field Peak that will help in understanding this concept and estimating if the value is realistic for a given antenna. The summation in Eq. 1.1 is the complex sum of all the measured data. For the region directly in front of the antenna where the phase is relatively constant, this sum times the data point spacing, is approximately the "volume" under the amplitude curve, and the greater this volume, the greater the gain of the antenna. Also for directive antennas, the Far-Field Peak, minus the normalized amplitude at the reference point is approximately the square of the effective Area of the antenna in dB $(\text{meters})^2$. For the example in the table, 20 $\log(A_e) \approx -70.64 - (-43.0) = -27.64$ dBm^2, or $A_e \approx .042\ m^2$. The area of the antenna is 0.091 m^2, for an aperture efficiency of approximately 46%. This calculation is only approximate and is useful to estimate if the Far-Field Peak is reasonable, but should not be used in place of the complete calculation of gain and effective area.

Spherical Near-Field Measurements

The processing of spherical near-field data also produces a result referred to as the Far Field Peak and it is also related to the gain of the AUT and the probe. The spherical software power normalizes the spherical mode coefficients so that the results will be proportional to the AUT gain. The complexity of the near-to-far transformation for spherical prevents the derivation of a simple relation like Equation (1), however it can be shown that

$$G_P + G_{AUT} = FFP - 20\,\mathbf{log}\left|a_n\right| + M \tag{3}$$

where

a_n = AUT input amplitude normalized to the reference channel amplitude.

M=Impedance mismatch correction

In direct gain measurements, the AUT input amplitude is measured by connecting the AUT input transmission line directly to the probe output transmission line and recording the receiver reading.

The spherical software searches for the maximum amplitude point and identifies this as the Far Field Peak. When Peak(Global) normalization is selected, all the pattern cuts will be referenced to this peak value.

Equation (3) also applies to the Cylindrical software processing.