Simulation of the SNS DTL BPM High Frequency Performance

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This simulation examines the high frequency signal power of the DTL BPMs as a function of beam energy and beam micropulse shape, for the present design BPM.

============ basic constants ====================

$c := 2.997924 \cdot 10^{10}$ cm/sec $\qquad$ $Mc2 := 939.28$ MeV

============ beam properties ====================

$Ib := 0.038 \qquad f := 402.5 \cdot 10^{6} \qquad w := 2 \cdot \pi \cdot f$

$$gam(E) := 1 + \frac{E}{Mc2} \qquad bgam(E) := \sqrt{gam(E)^2 - 1} \qquad beta(E) := \frac{bgam(E)}{gam(E)}$$

============= BPM =====================

$a := 1.44$ cm, effective radius $\qquad$ $L := 3.4$ cm, effective length

$Z := 50$ ohms $\qquad$ $phi := 60$ degrees, electrode width

$$argBPM(n, E) := \frac{n \cdot w \cdot L}{2 \cdot c} \cdot \left(1 + \frac{1}{1}\right)$$

argument for BPM with shorted electrodes

====================== Bessel factor =======================

This is the low-beta effect

$$argBes(n, E) := \frac{n \cdot w \cdot a}{bgam(E) \cdot c} \qquad Bes(n, E) := \frac{1}{I0(argBes(n, E))}$$

dB change

$$dBBes(n, E) := 20 \cdot \log(Bes(n, E))$$

===================== Fourier transform of pulse shape ==================

$FWAB(sig) := 4.472 \cdot 10^{-12} \cdot sig$ Full width at base of parabolic micropulse, in terms of the rms width sig(ps).

$$alpha(n, sig) := n \cdot \pi \cdot FWAB(sig) \cdot f$$

$$Am(n, sig) := 3 \cdot \left(\frac{\sin(alpha(n, sig))}{alpha(n, sig)^3} - \frac{\cos(alpha(n, sig))}{alpha(n, sig)^2}\right)$$

Fourier harmonic amplitudes for parabolic bunch shape

$dBpulse(n, sig) := 10 \cdot \log\left(Am(n, sig)^2\right)$ dB change

================== coax cable==============================

$atten := -2$ approx attenuation for 50 m of 1/2" heliax at 400 MHz

$dBatten(n) := atten\cdot\sqrt{n}$ dB change

=============== dBm power for basic BPM ================

$$V(n,E) := \sqrt{2}\cdot\frac{phi}{360}\cdot Ib\cdot Z\cdot \sin(argBPM(n,E))$$

$$pwr(n,E) := 1000\frac{V(n,E)^2}{Z}$$ milliwatts

$dBm(n,E) := 10\cdot\log(pwr(n,E))$ dBm output for basic BPM without corrections

================= total power level ======================================

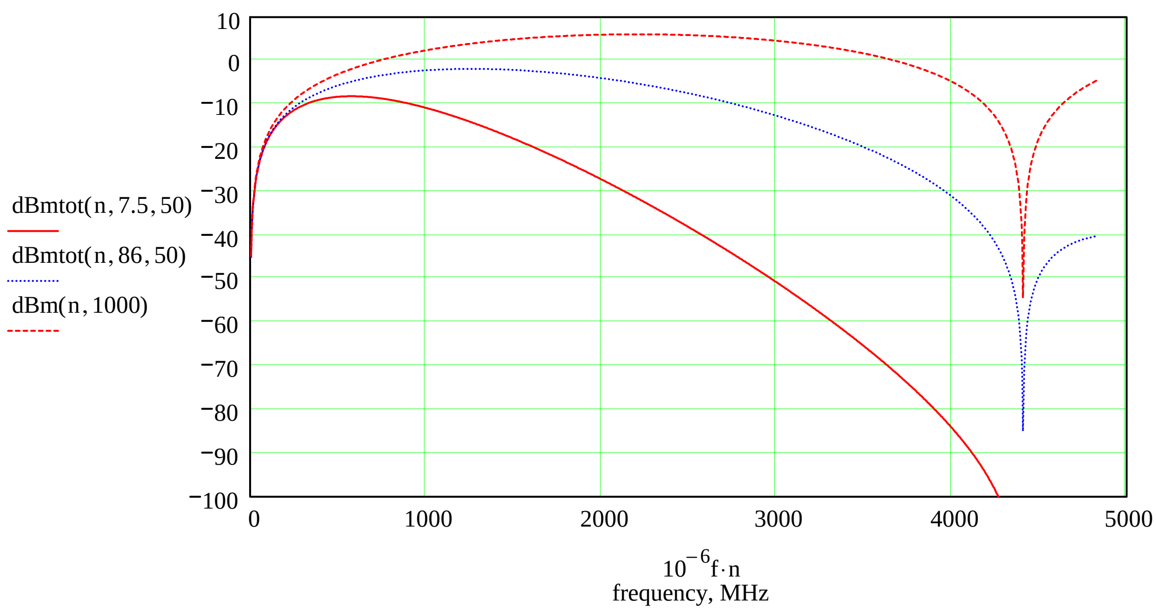
$$dBmtot(n,E,sig) := dBm(n,E) + dBBes(n,E) + dBatten(n) + dBpulse(n,sig)$$

Example $dBm(10,86) = -5.339$ $dBBes(10,86) = -12.21$ $dBatten(10) = -6.325$

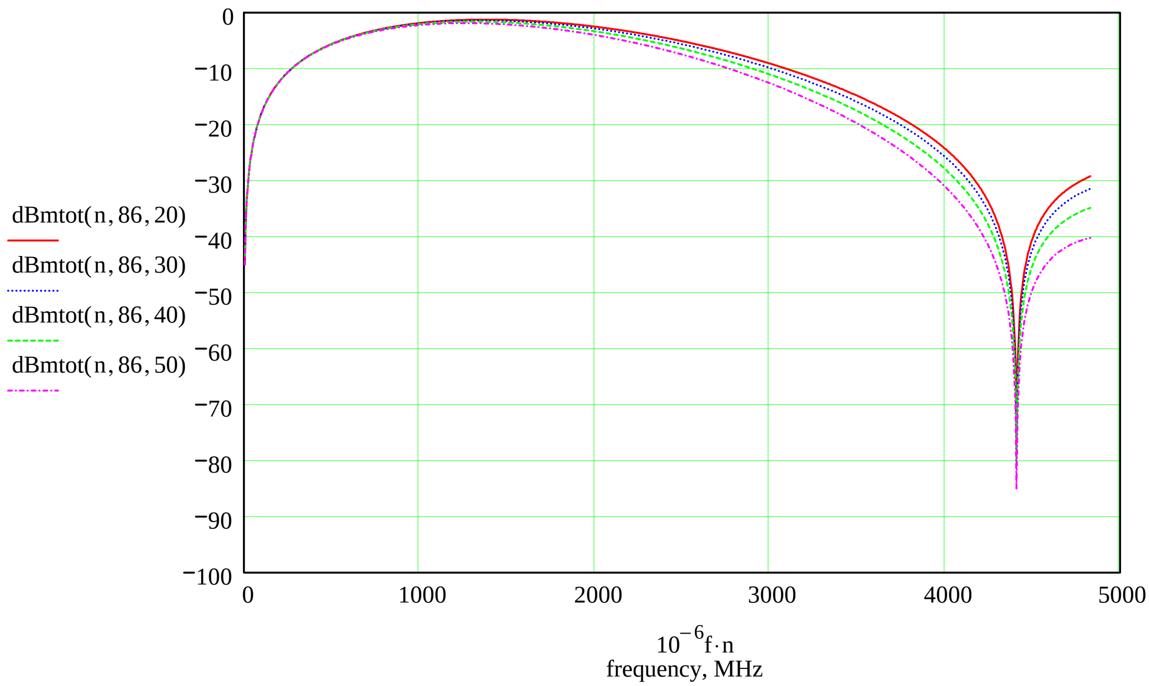
$dBpulse(10,50) = -8.004$ $dBmtot(10,86,50) = -31.878$

$n := 0.01, 0.02 .. 12$

Signal power vs. frequency for the basic BPM, and for 7.5 and 86 MeV



Effect of bunch length on output power at 86 MeV



Because the effective length of the BPM is known to only about +/-3%, the signal power above 4 GHz is very uncertain. It is clear that the best high frequency measurements would be between 3 and 4 GHz.

The approximate cutoff frequencies are (using the effective radius of BPM):

$$fTE := \frac{10^{-9}\cdot 3.832\cdot c}{2\cdot\pi\cdot a} \qquad fTE = 12.697$$ GHz, TE mode

$$fTM := \frac{10^{-9}\cdot 2.405\cdot c}{2\cdot\pi\cdot a} \qquad fTM = 7.969$$ GHz, TM mode

Measurements probably should be limited to about 4 GHz or lower.

Amplitudes of the 10th harmonic (about 4 GHz) are:

$10\cdot 10^{-9}\cdot f = 4.025$ GHz

$dBmtot(10, 86, 10) = -24.153$ dBm, 10 ps rms bunch length

$dBmtot(10, 86, 20) = -25.006$ dBm, 20 ps rms bunch length

$dBmtot(10, 86, 30) = -26.486$ dBm, 30 ps rms bunch length

$dBmtot(10, 86, 40) = -28.703$ dBm, 40 ps rms bunch length

$dBmtot(10, 86, 50) = -31.878$ dBm, 50 ps rms bunch length