Simulation of the SNS SCL BPM High Frequency Performance

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This simulation examines the high frequency signal power of the SCL 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 $Mc2 := 939.28$ MeV

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

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

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

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

$a := 3.91$ cm, effective radius $L := 5.35$ cm, effective length

$Z := 50$ ohms $phi := 45$ 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

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

$atten := -2$ dB, 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 ======================================

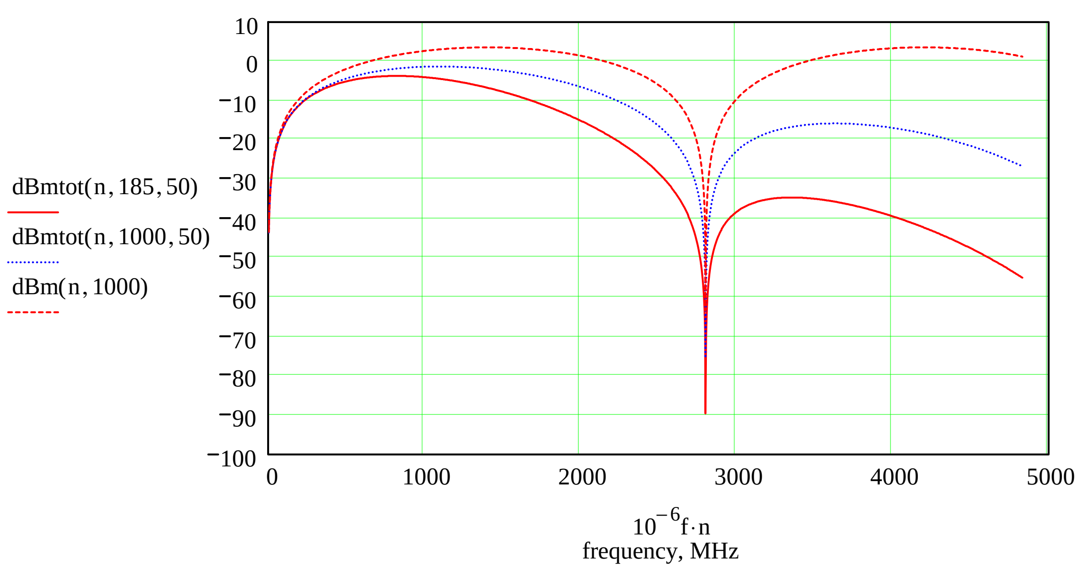
$$dBmtot(n,E,sig) := dBm(n,E) + dBBes(n,E) + dBatten(n) + dBpulse(n,sig)$$

Example $dBm(6,185) = -3.996$ $dBBes(6,185) = -13.83$ $dBatten(6) = -4.899$

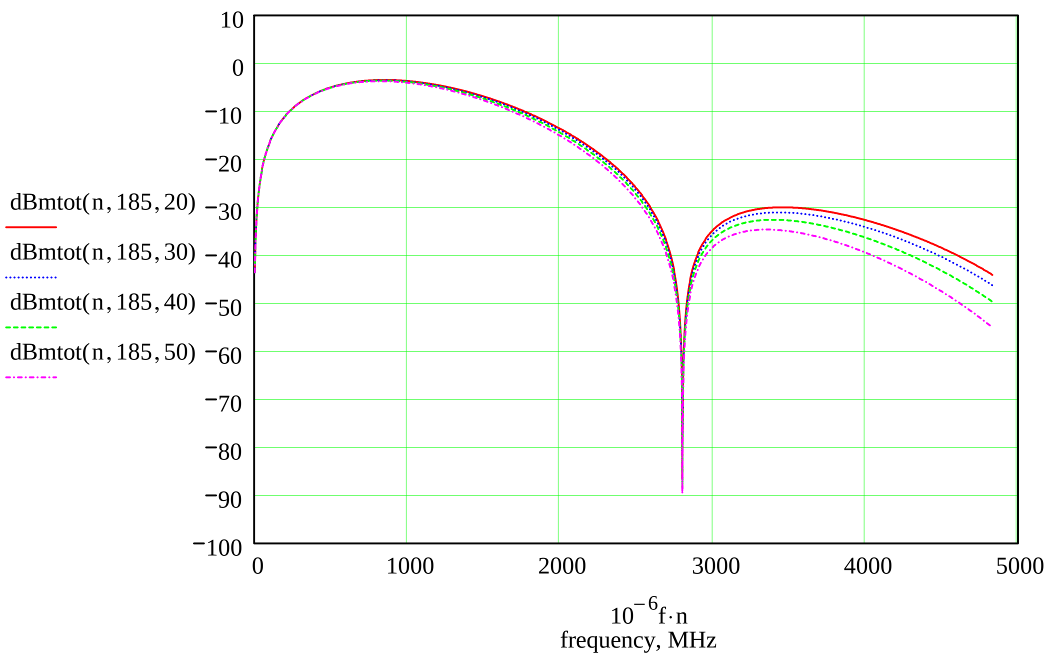
$dBpulse(6,50) = -2.612$ $dBmtot(6,185,50) = -25.337$

$n := 0.01, 0.02 .. 12$

Signal power vs. frequency for the basic BPM, and for 185 and 1000 MeV



Effect of bunch length on output power at 185 MeV



Because the effective length of the BPM is known to only about +/-3%, the signal power between 2.5 and 3 GHz is very uncertain. It is clear that the best high frequency measurements would be between 3 and 4 GHz, except for the existance of propagating modes abouve cutoff.

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

$$fTE := \frac{10^{-9} \cdot 3.832 \cdot c}{2 \cdot \pi \cdot a} \qquad fTE = 4.676$$ GHz, TE mode

$$fTM := \frac{10^{-9} \cdot 2.405 \cdot c}{2 \cdot \pi \cdot a} \qquad fTM = 2.935$$ GHz, TM mode

Measurements probably should be limited to about 2.5 GHz or lower.

Amplitudes of the 6th harmonic (about 2.4 GHz) are:

$$6 \cdot 10^{-9} \cdot f = 2.415$$ GHz

$dBmtot(6, 185, 10) = -22.825$ dBm, 10 ps rms bunch length

$dBmtot(6, 185, 20) = -23.128$ dBm, 20 ps rms bunch length

$dBmtot(6, 185, 30) = -23.639$ dBm, 30 ps rms bunch length

$dBmtot(6, 185, 40) = -24.369$ dBm, 40 ps rms bunch length

$dBmtot(6, 185, 50) = -25.337$ dBm, 50 ps rms bunch length

Measurement of bunch length using Fourier harmonics appears to be very difficult.