Long range wakefields for C-band: preliminary results with uncoupled model

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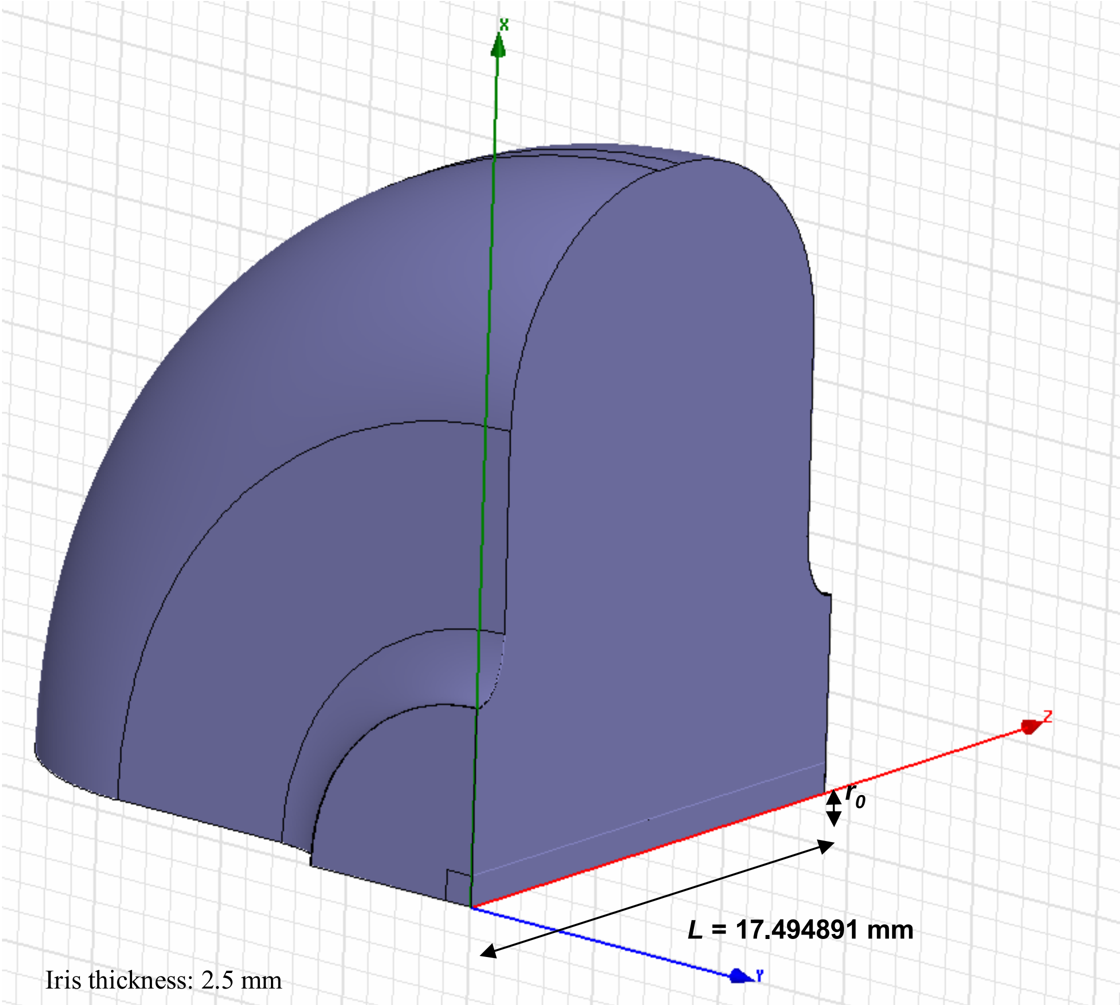
Cell (C-band: 5.712 GHz)	Iris (mm)	Radius (mm)
1	7.276	22.48142
27	6.882	22.3526
55	6.458	22.2245
82	6.049	22.1114
110	5.625	22.00499

from J.-Yves computations



Loss factor:

$$K_l = \frac{\left|\int E_z(z)\cdot e^{ikz}dz\right|^2}{4U}$$

Transverse kick (using Panofsky-Wenzel):

$$K_t = \frac{\left|\int E_z(r_0,z)\cdot e^{ikz}dz\right|^2}{kr_0\cdot 4U}\cdot\frac{1}{r_0 L}$$

HOM passbands (uncoupled model circuit):

$$\frac{1}{\nu^2} = \frac{1}{\overline{\nu}^2} + \kappa\cos\underbrace{\left(\frac{(p-1)\pi}{N}\right)}_{\Phi}$$

$$\overline{\nu} = \sqrt{\frac{2\nu_\pi^2\nu_0^2}{\nu_\pi^2+\nu_0^2}}$$

$$\eta = \frac{\nu_\pi^2-\nu_0^2}{\nu_\pi^2+\nu_0^2} \qquad \kappa = \frac{1}{2}\frac{2\eta}{\overline{\nu}^2}$$

(*The transverse wakefield of a detuned X-band accelerator structure*, K. Bane, R. Gluckstern, SLAC-PUB-5783, 1992)

Procedure for longitudinal wakes:

The uncoupled model is considered for a preliminary study of the long range longitudinal wakefields. The steps of the analysis are the following:

1. For the present C-band design, compute the main rf parameters (f, Q, R/Q, loss factor) for the first 5 modes TM – like, for the phase advance 0 and pi, for the cell geometries n. 1, 55, 110.

2. For each cell geometry, use the rf parameters computed for the 0, pi phase advance and the circuit model formulas in order to obtain the passband of a corresponding infinite structure 'constant impedance'.

3. Find the synchronous phases and the synchronous frequencies for each passband.

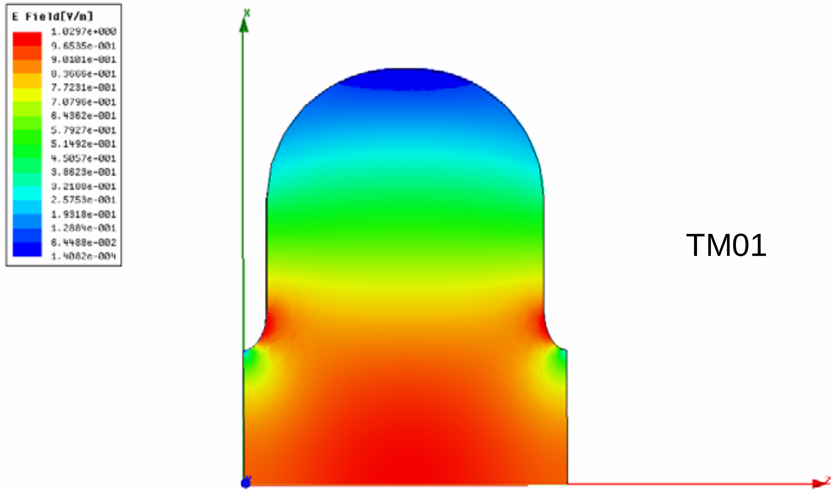
4. Use the synchronous phases to compute the synchronous Q and loss factors by means of fitting procedure applied to plots at step 1.

5. Compute the longitudinal wakes (C-band present design).

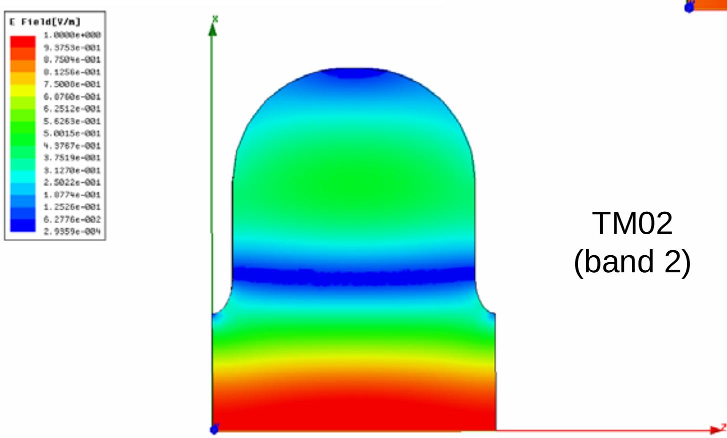
This analysis suffers the limits of the uncoupled model and also the quality of the fits at step 4 (because of the choice of only two phase advances at step 1).

Step 1

(examples for phase advance = 0 deg)

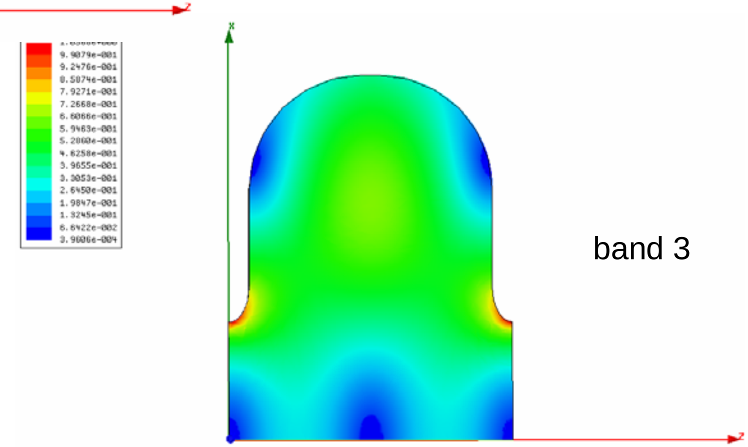


TM01

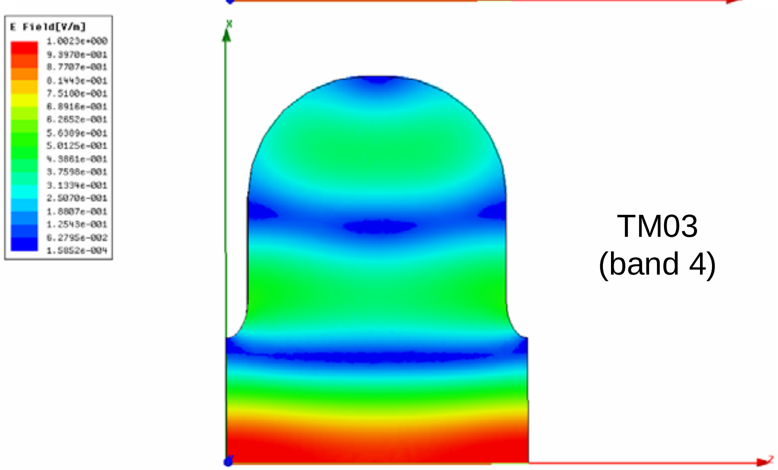


TM02
(band 2)

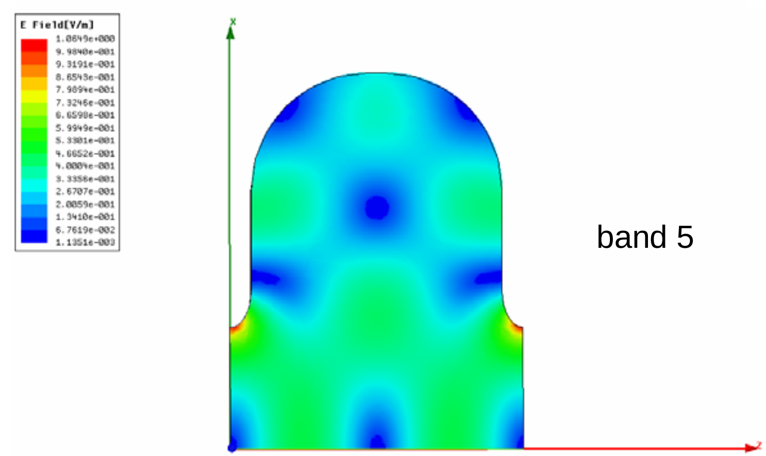
H
O
M



band 3



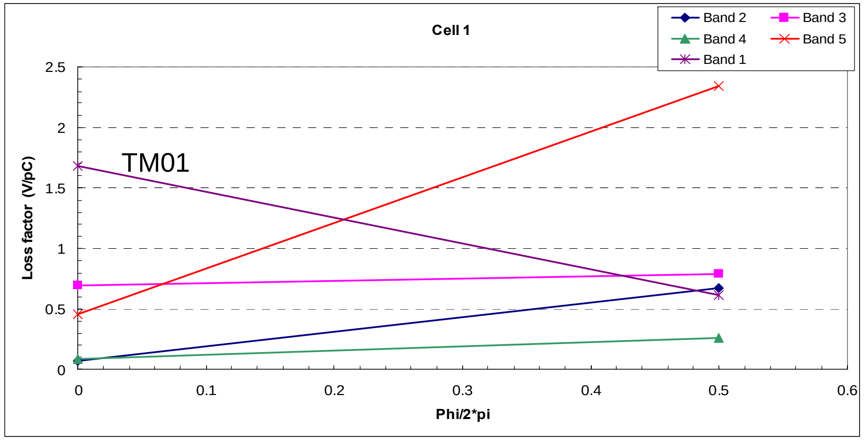
TM03
(band 4)

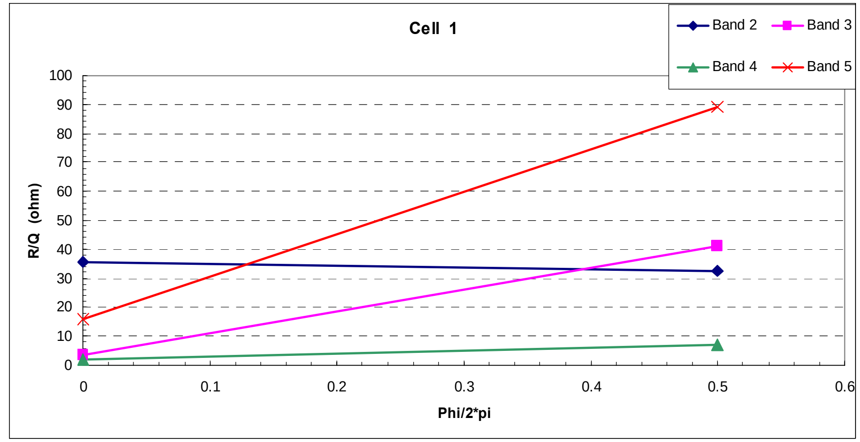


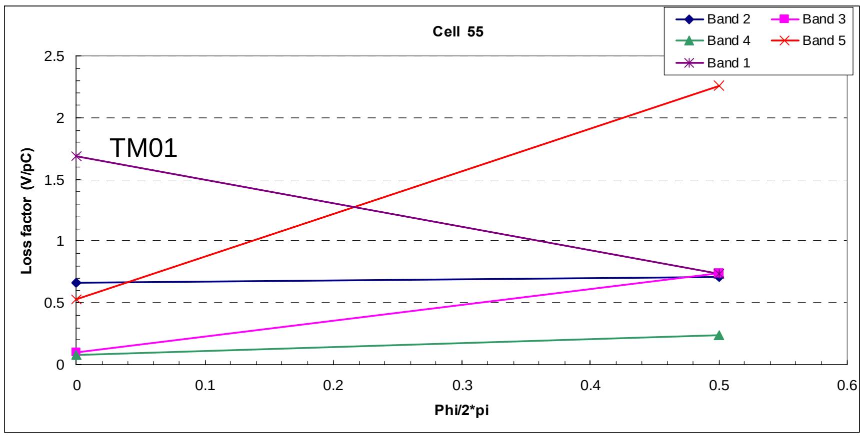
band 5

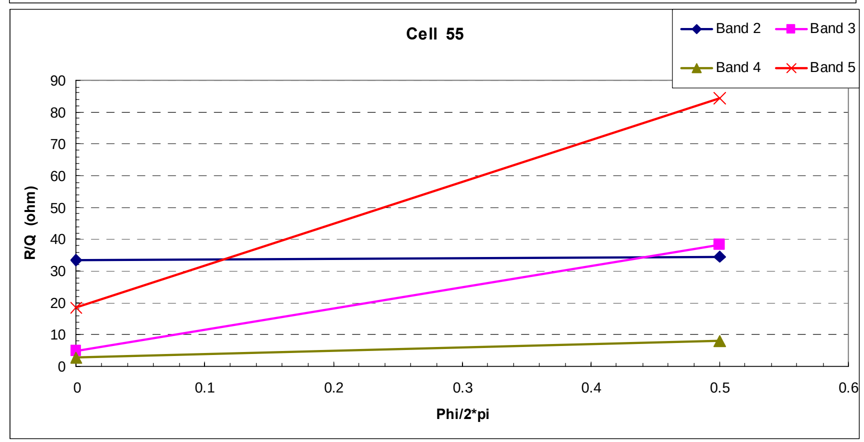
Loss factor: $K = \dfrac{\left|\int E_z(z) \cdot e^{ikz} dz\right|^2}{4U}$

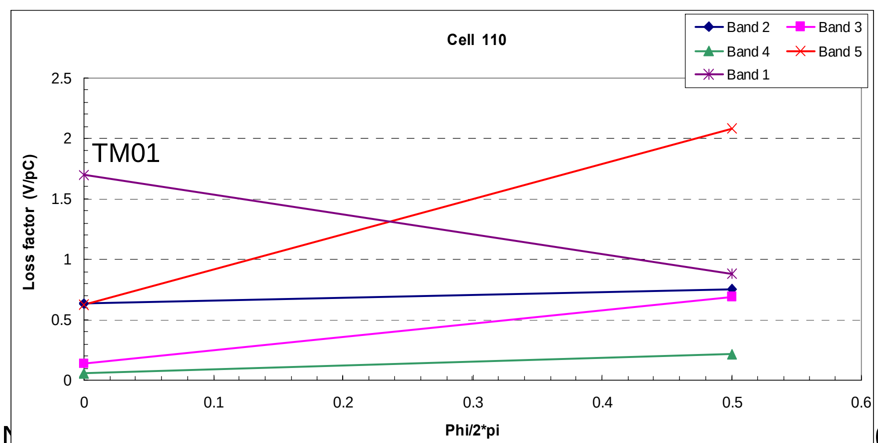
Impedance: $R/Q = \dfrac{\left|\int E_z(z) \cdot e^{ikz} dz\right|^2}{\omega U}$

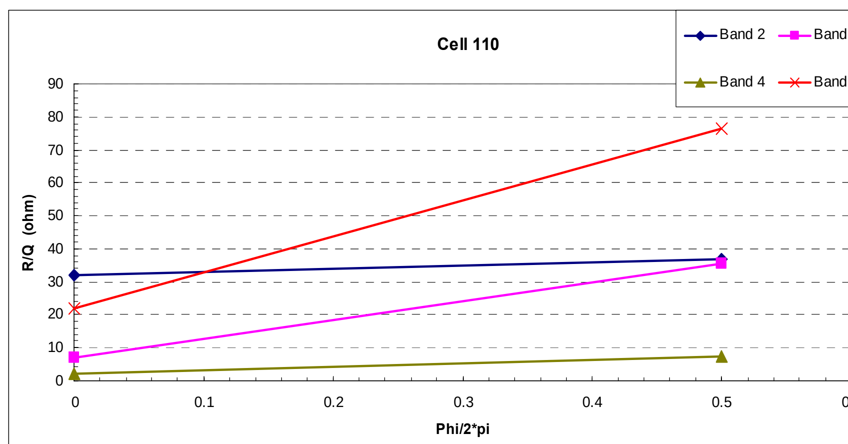


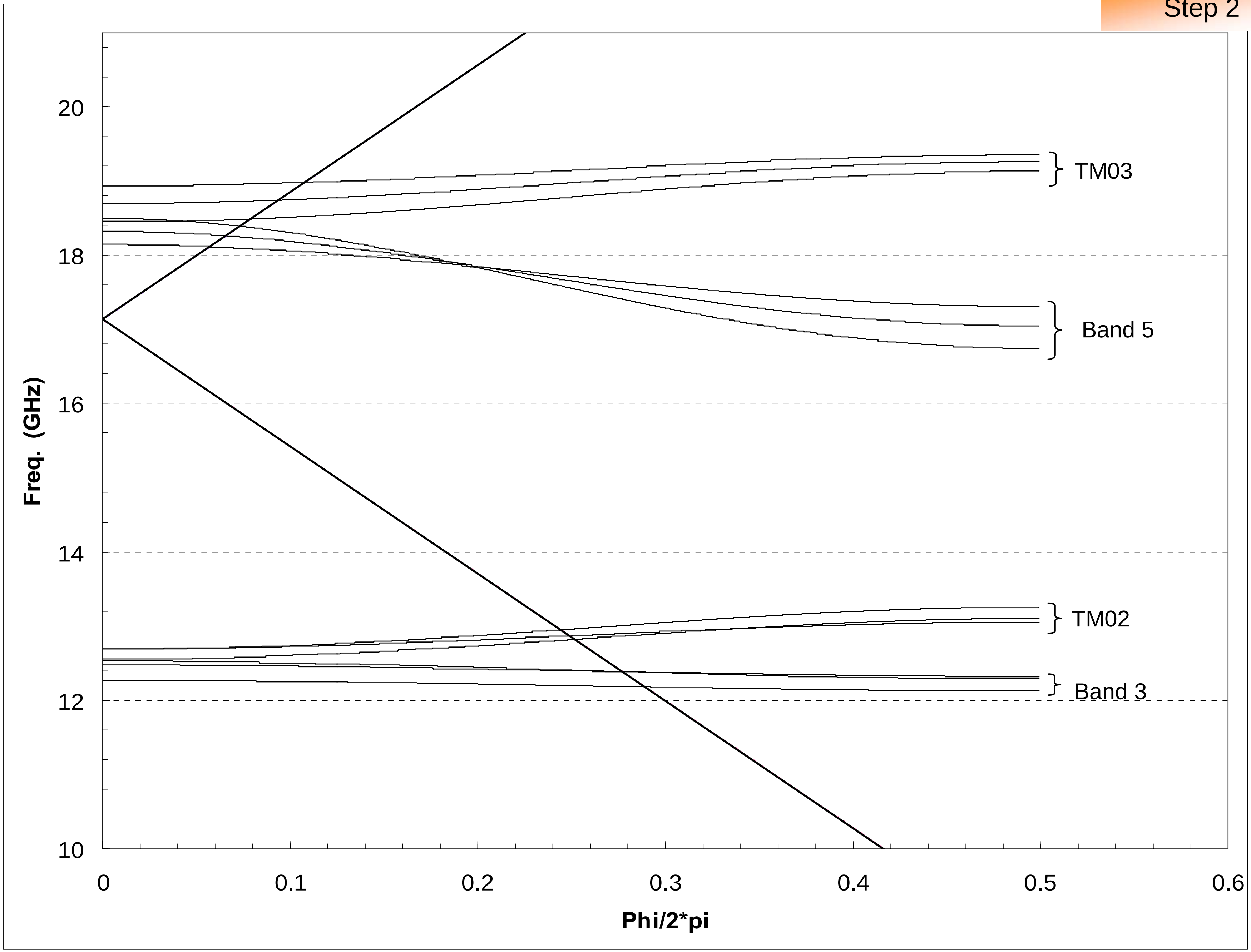


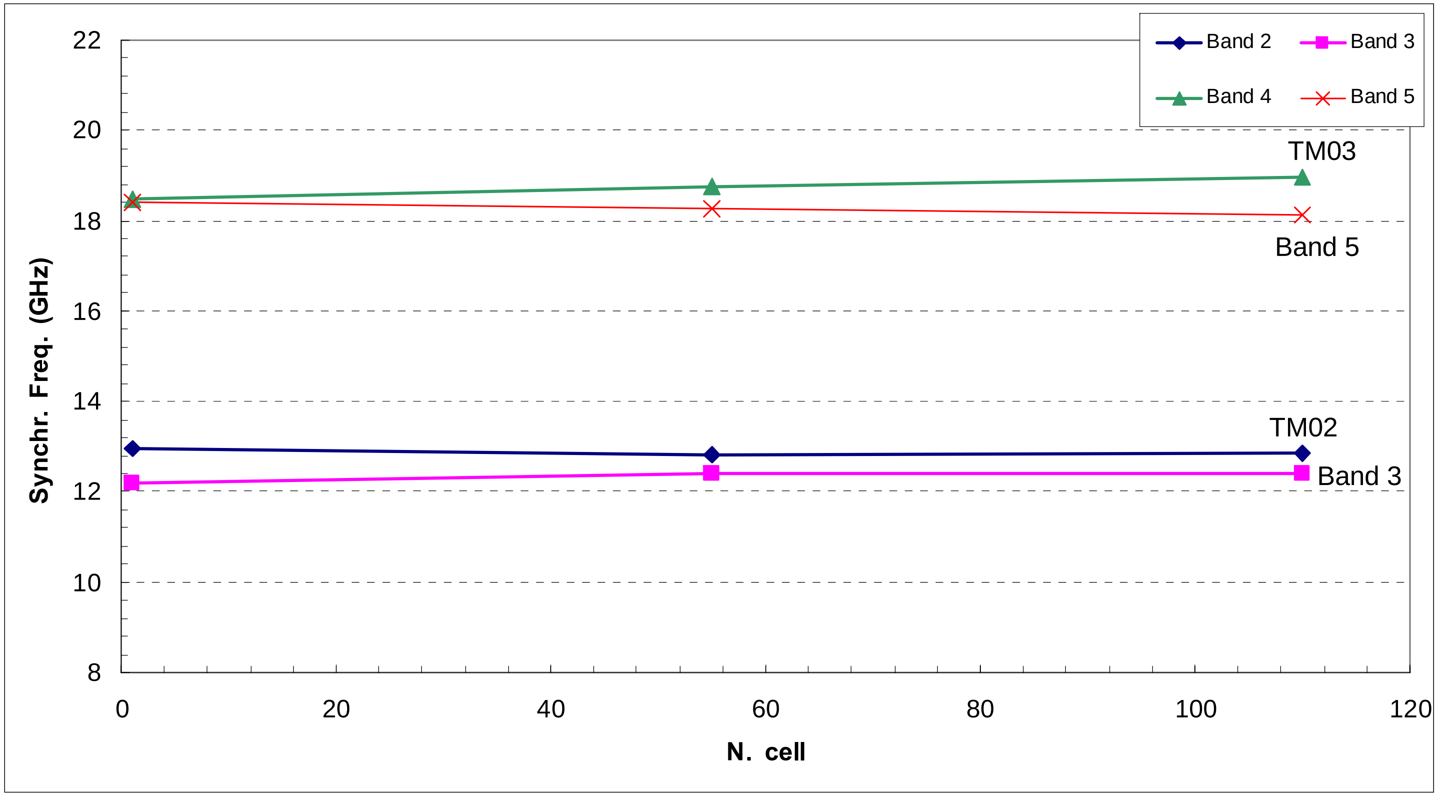









20
18
16
14
12
10
Freq. (GHz)
TM03
Band 5
TM02
Band 3
0
0.1
0.2
0.3
0.4
0.5
0.6
Phi/2*pi



Band 2

	Freq. s. (GHz)	Phi s. (deg)
Cell 1	12.95051612	87.975
Cell 55	12.82234396	90.675
Cell 110	12.86876271	89.55

Band 3

Freq. s. (GHz)	Phi s. (deg)
12.17859516	104.175
12.38288336	99.9
12.38266145	99.9

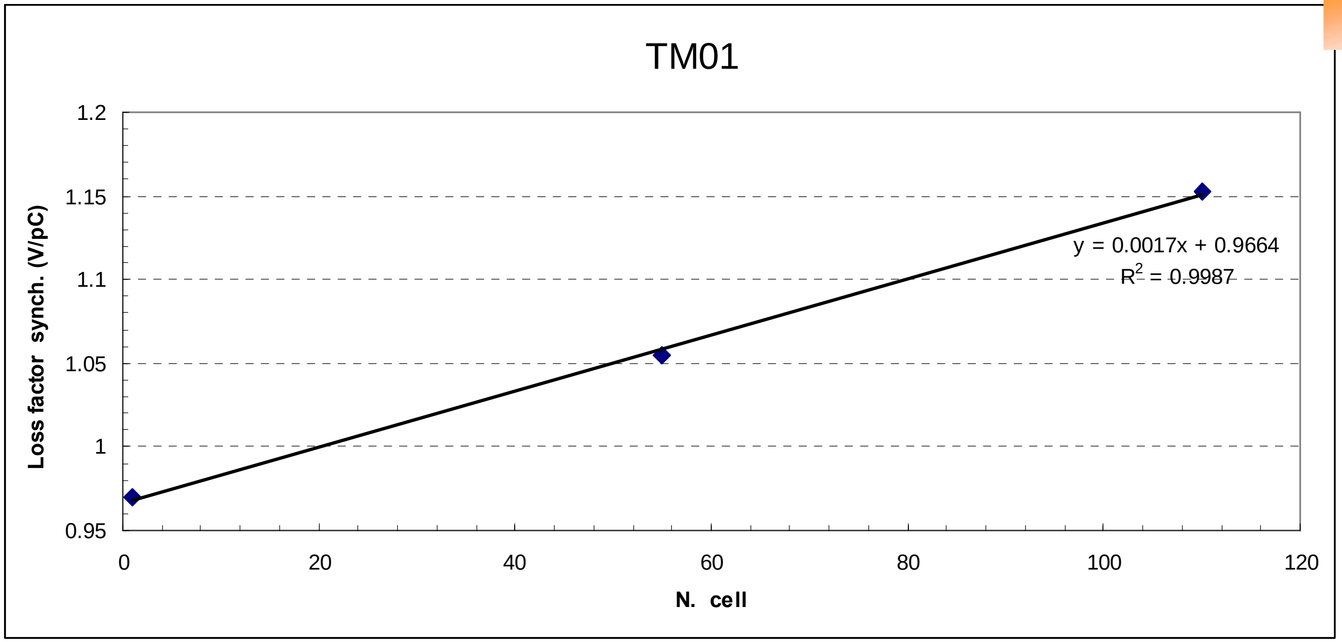
Band 4

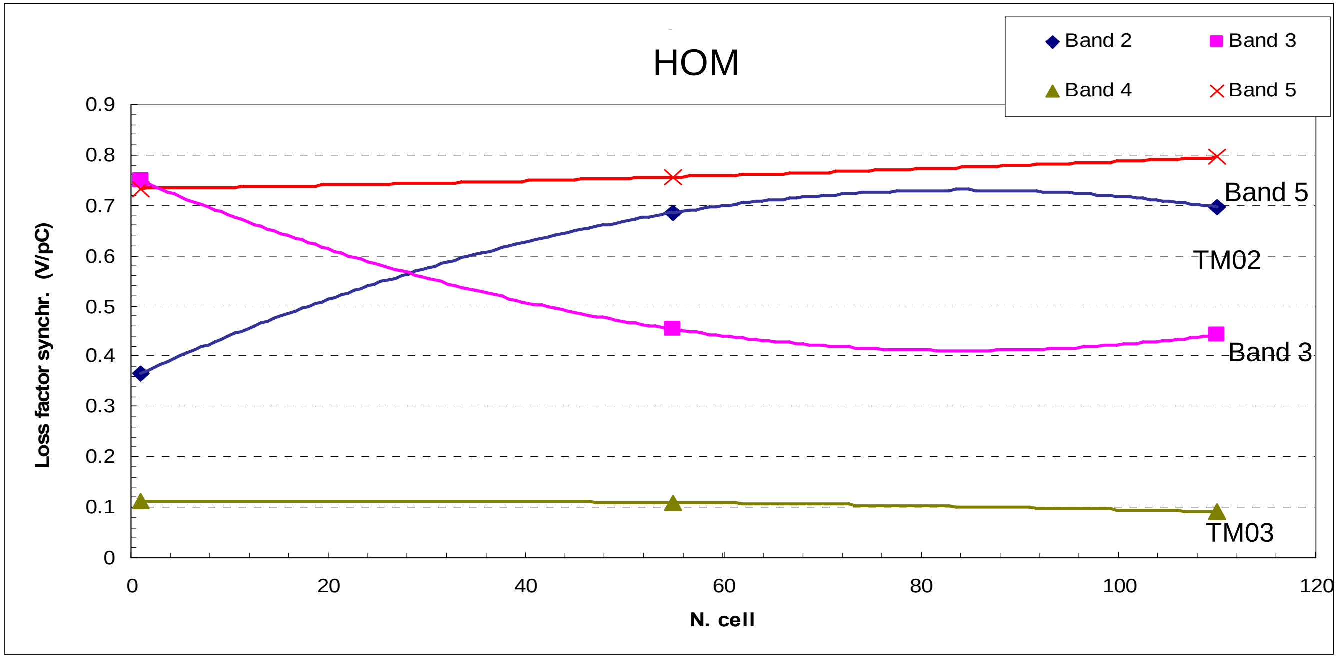
	Freq. s. (GHz)	Phi s. (deg)
Cell 1	18.48896819	28.35
Cell 55	18.7410904	33.75
Cell 110	18.97839869	38.7

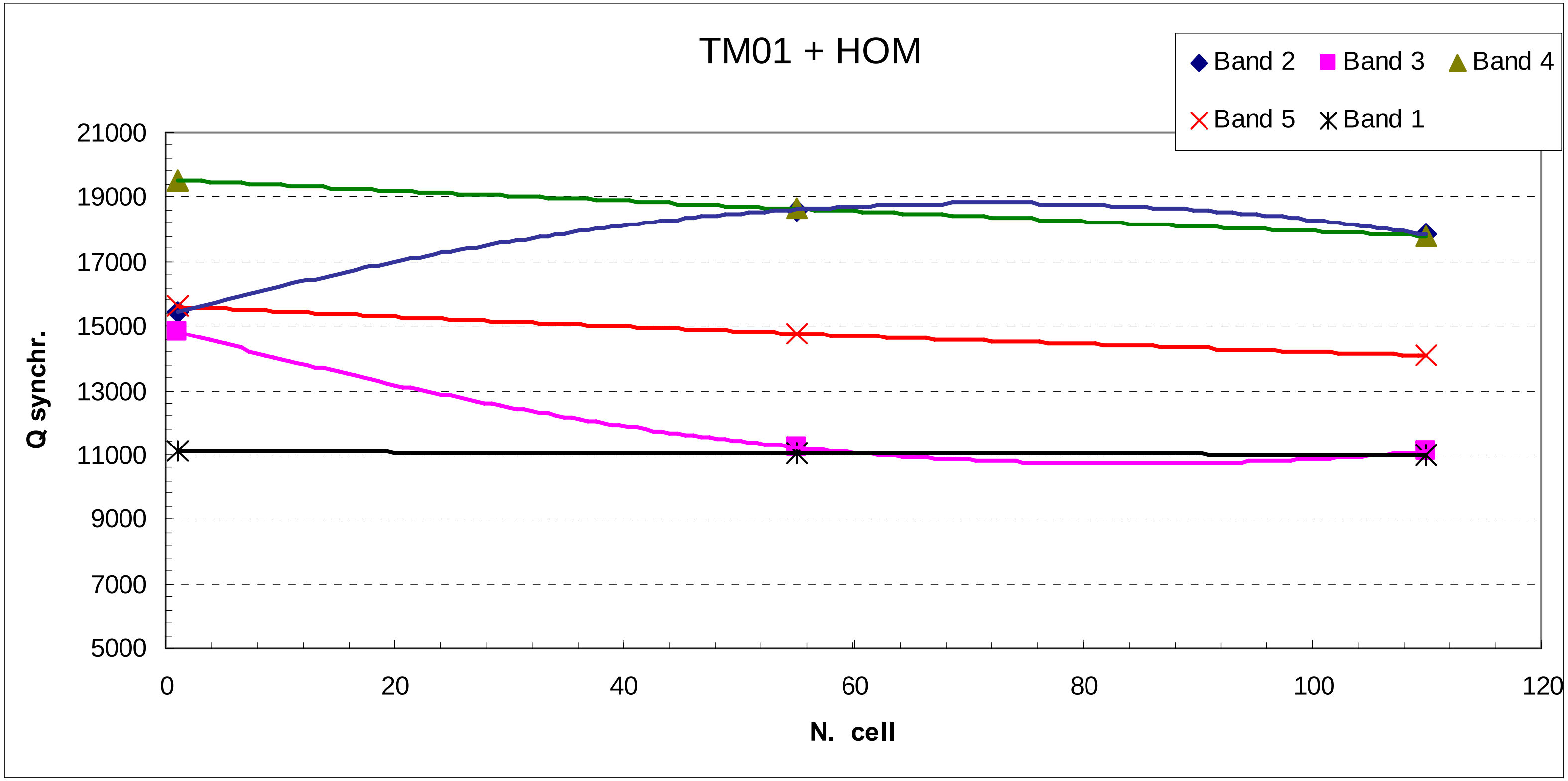
Band 5

Freq. s. (GHz)	Phi s. (deg)
18.39374512	26.325
18.26361233	23.625
18.11609837	20.7

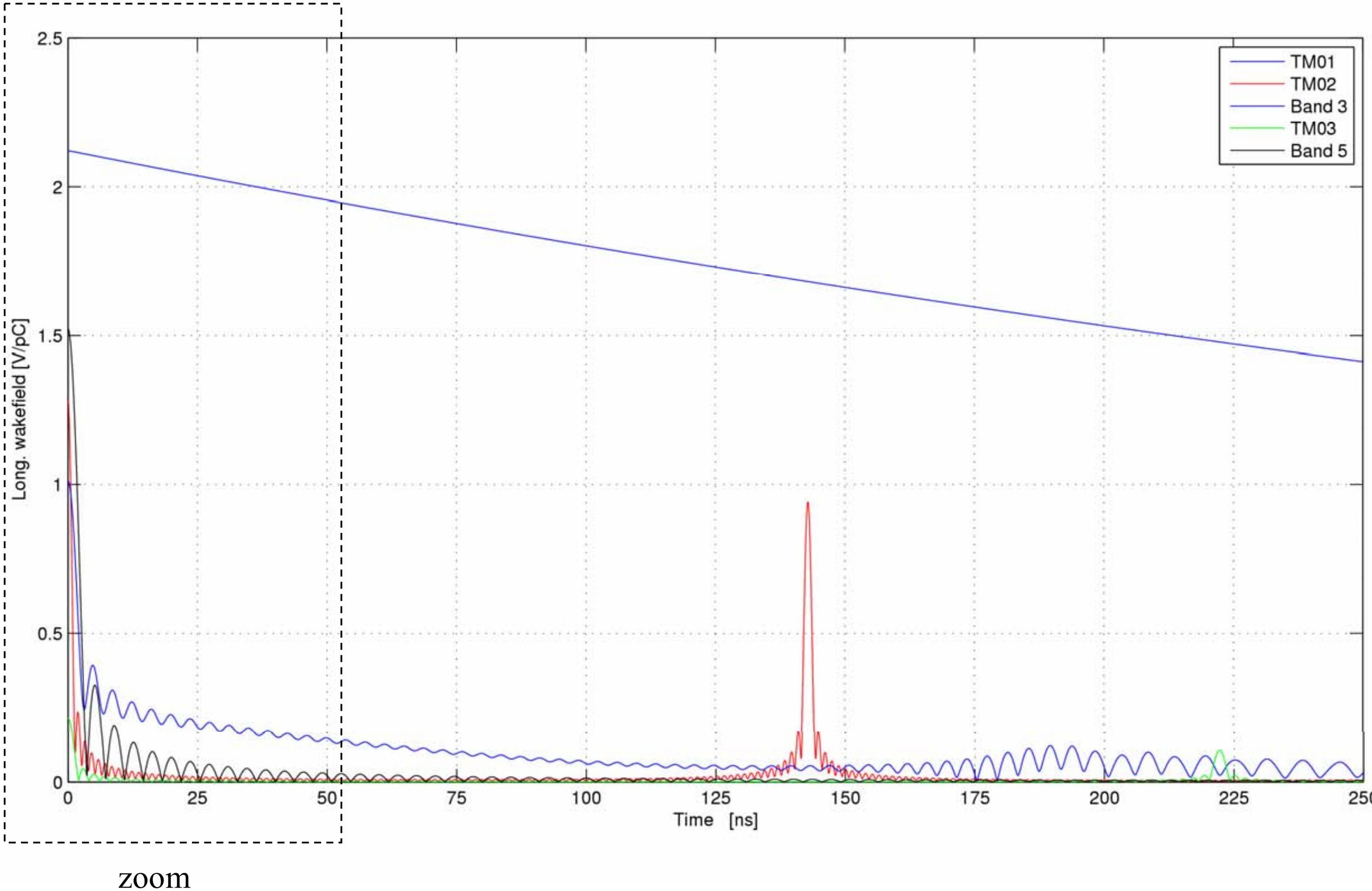
Step 4


TM01
1.2
1.15
1.1
1.05
1
0.95
0
20
40
60
80
100
120
Loss factor synch. (V/pC)
N. cell
y = 0.0017x + 0.9664
R2 = 0.9987

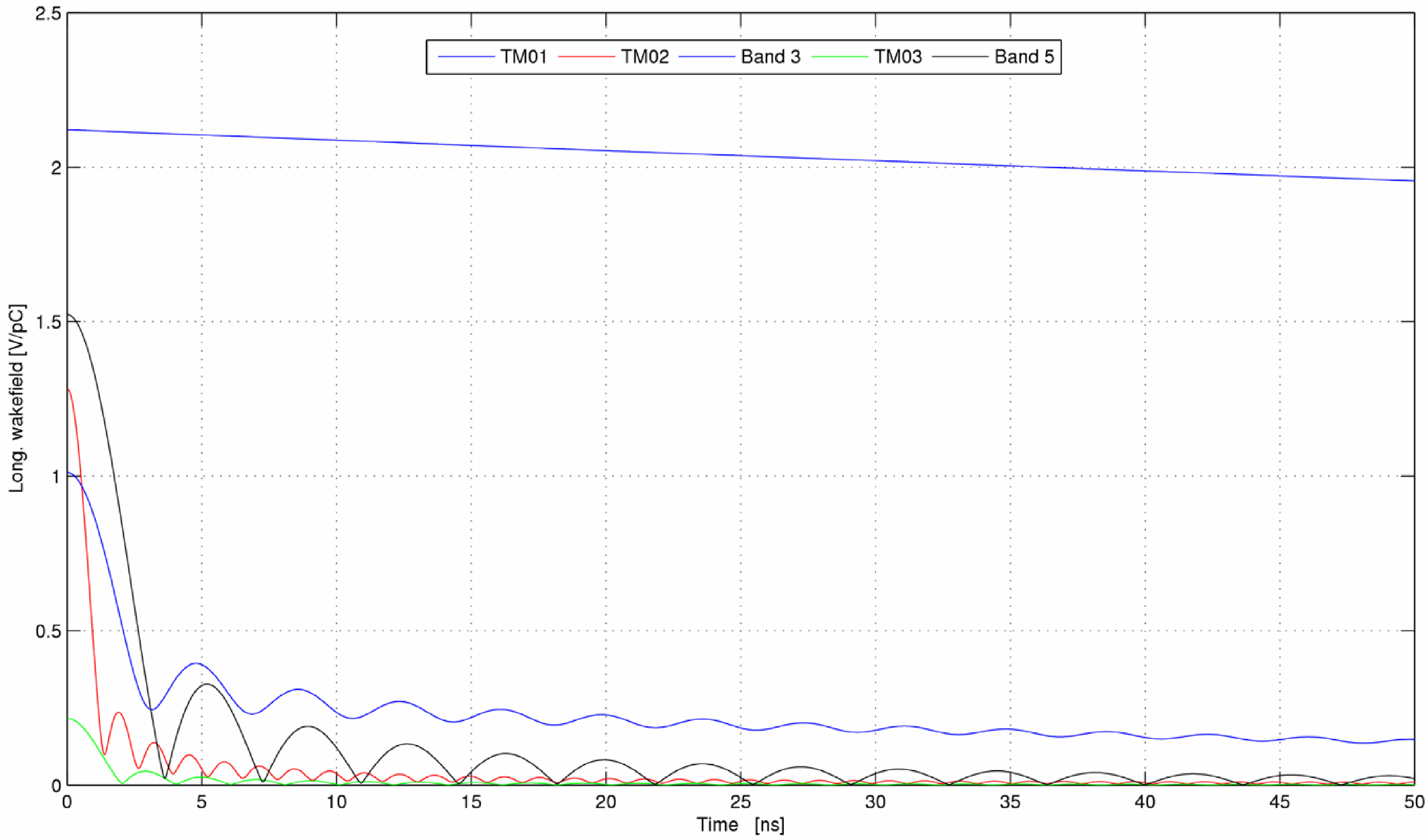

HOM
Band 2
Band 3
Band 4
Band 5
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
20
40
60
80
100
120
Loss factor synchr. (V/pC)
N. cell
Band 5
TM02
Band 3
TM03


TM01 + HOM
Band 2
Band 3
Band 4
Band 5
Band 1
Q synchr.
21000
19000
17000
15000
13000
11000
9000
7000
5000
0
20
40
60
80
100
120
N. cell

$$W = \frac{2}{N}\left|\sum K_i \exp\left[2\pi i f_{s,i} t \cdot \left(1 + \frac{i}{2Q_{s,i}}\right)\right]\right| \quad , \quad K = \frac{\left|\int E_z(z)\cdot e^{ikz}dz\right|^2}{4U}$$



Zoom 0-50 ns



TM01
TM02
Band 3
TM03
Band 5
Long. wakefield [V/pC]
Time [ns]
0
0.5
1
1.5
2
2.5
0
5
10
15
20
25
30
35
40
45
50

Procedure for transverse wakes:

The same uncoupled model used for the analysis of the long range longitudinal wakefields is considered for a preliminary study of the long range transverse wakes. The step of the analysis are the following:

1. For the present C-band design, compute the main rf parameters (f, Q, R/Q, loss factor) for the first two dipole modes for the phase advance 0 and pi, for the cell geometries n. 1, 27, 55, 82, 110.

2. For each cell geometry, use the rf parameters computed for the 0, pi phase advance and the circuit model formulas in order to obtain the passband of a corresponding infinite structure ‘constant impedance’.

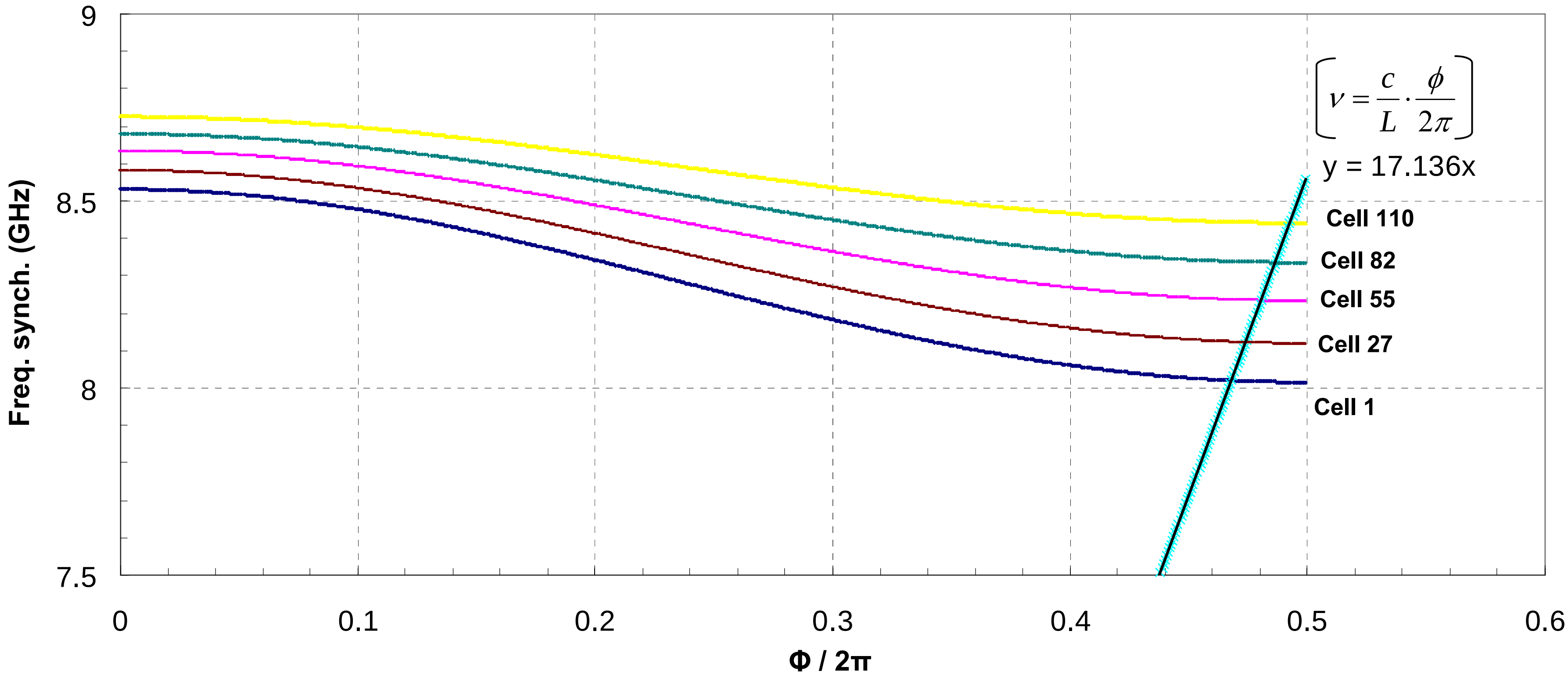
3. Find the synchronous phases and the synchronous frequencies for each passband. Verify the synchr. frequ. by means of HFSS simulations.

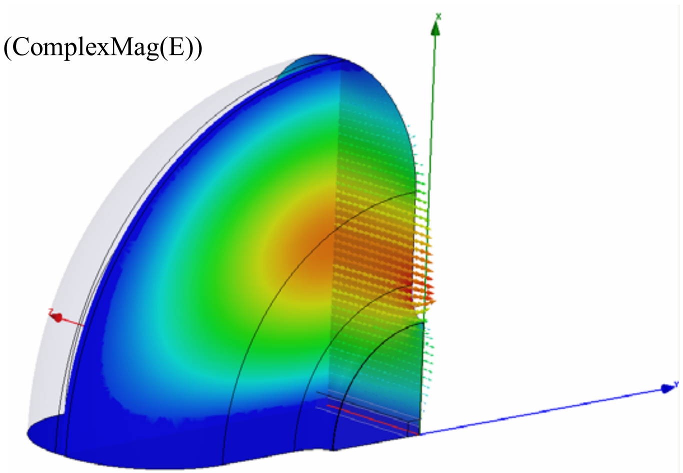
4. Use the latest HFSS simulations to obtain plots of the synchronous Qs and kicks vs number of cell.

5. Compute the wakes: examples for C-band present design and gaussian like distribution of synchr. frequ.

This analysis suffers the limits of the uncoupled model (above all if applied to the second dipole band), and the form of the passbands extrapolated at step 1 (with only two phase advances, 0 and pi).

First Dipole band HEM11 (for infinite periodic structures, and cells with fixed geometry) :

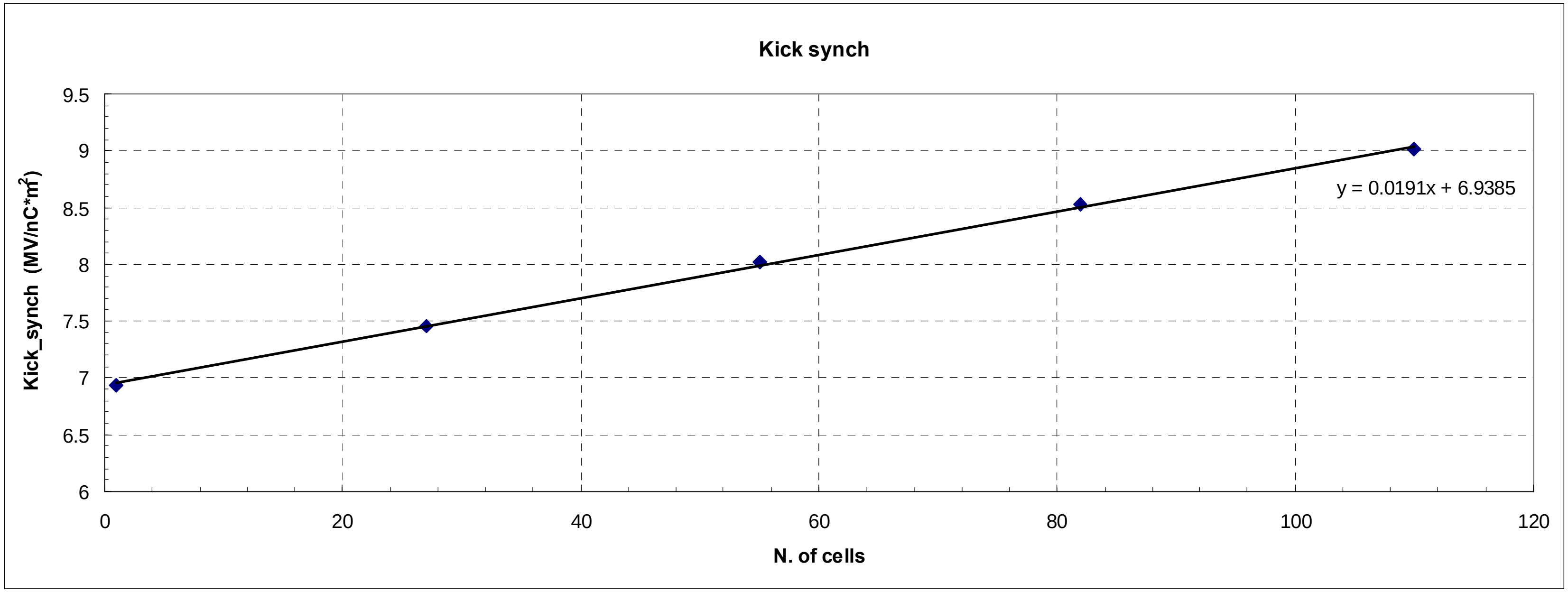


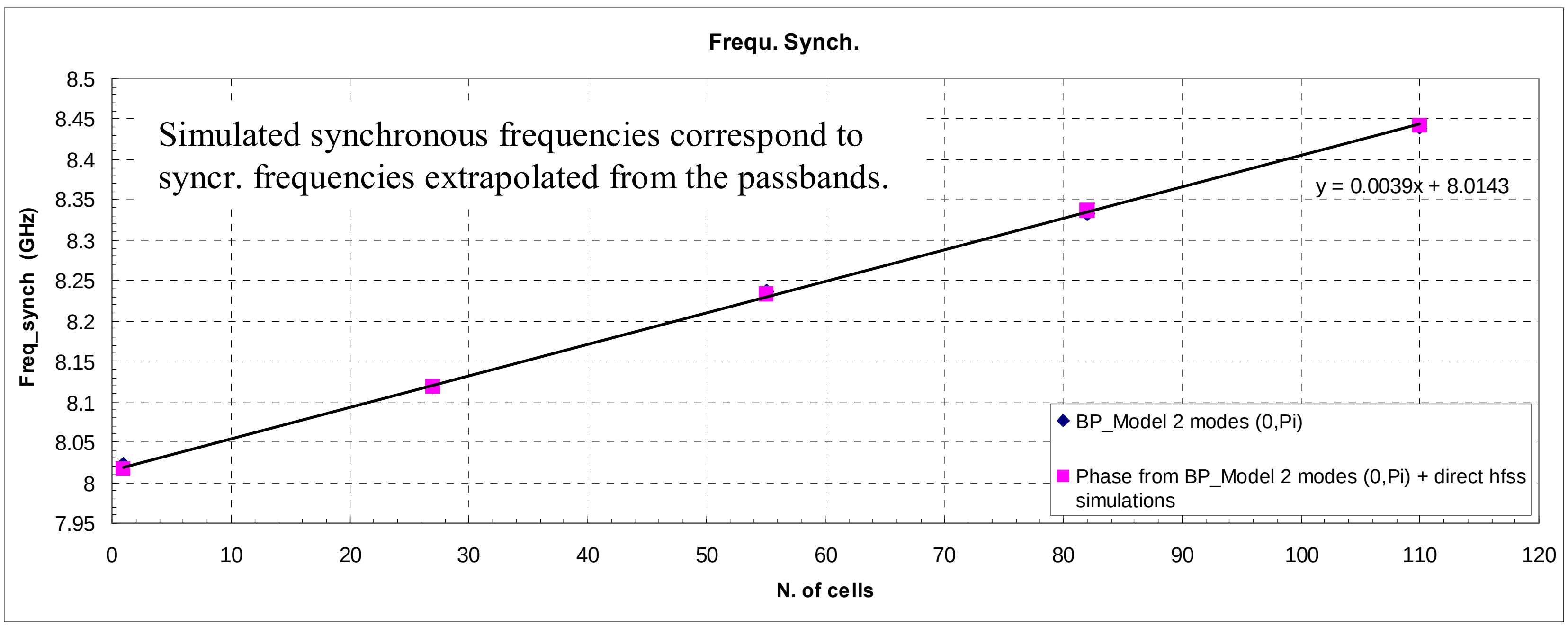


Synchronous frequencies and phase advances:

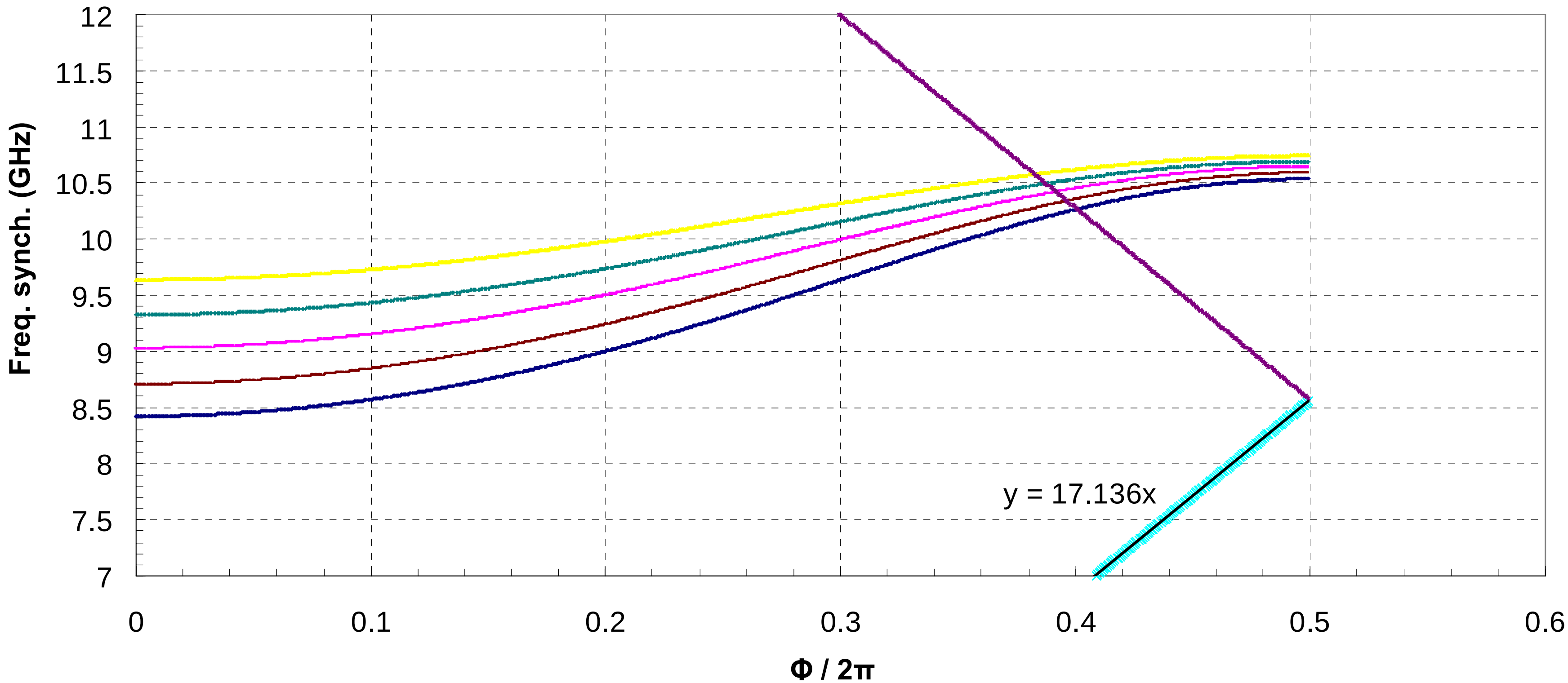
N. Cell	Freq. synch. (GHz)	Phase Φ / 2π
1	8.021790156	0.468125
27	8.118180158	0.47375
55	8.23599016	0.480625
82	8.332380162	0.48625
110	8.439480164	0.4925

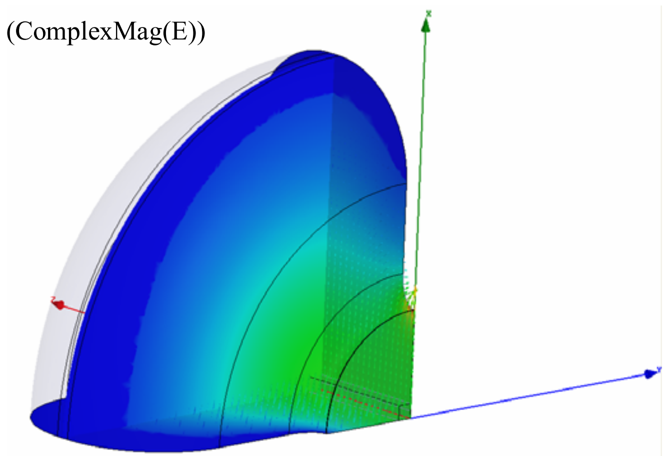
→ input for HFSS


Kick synch
Kick_synch (MV/nC*m^2)
N. of cells
y = 0.0191x + 6.9385


Frequ. Synch.
Simulated synchronous frequencies correspond to
syncr. frequencies extrapolated from the passbands.
Freq_synch (GHz)
N. of cells
y = 0.0039x + 8.0143
BP_Model 2 modes (0,Pi)
Phase from BP_Model 2 modes (0,Pi) + direct hfss simulations

Second Dipole band HEM01 (for infinite periodic structures, and cells with fixed geometry) :

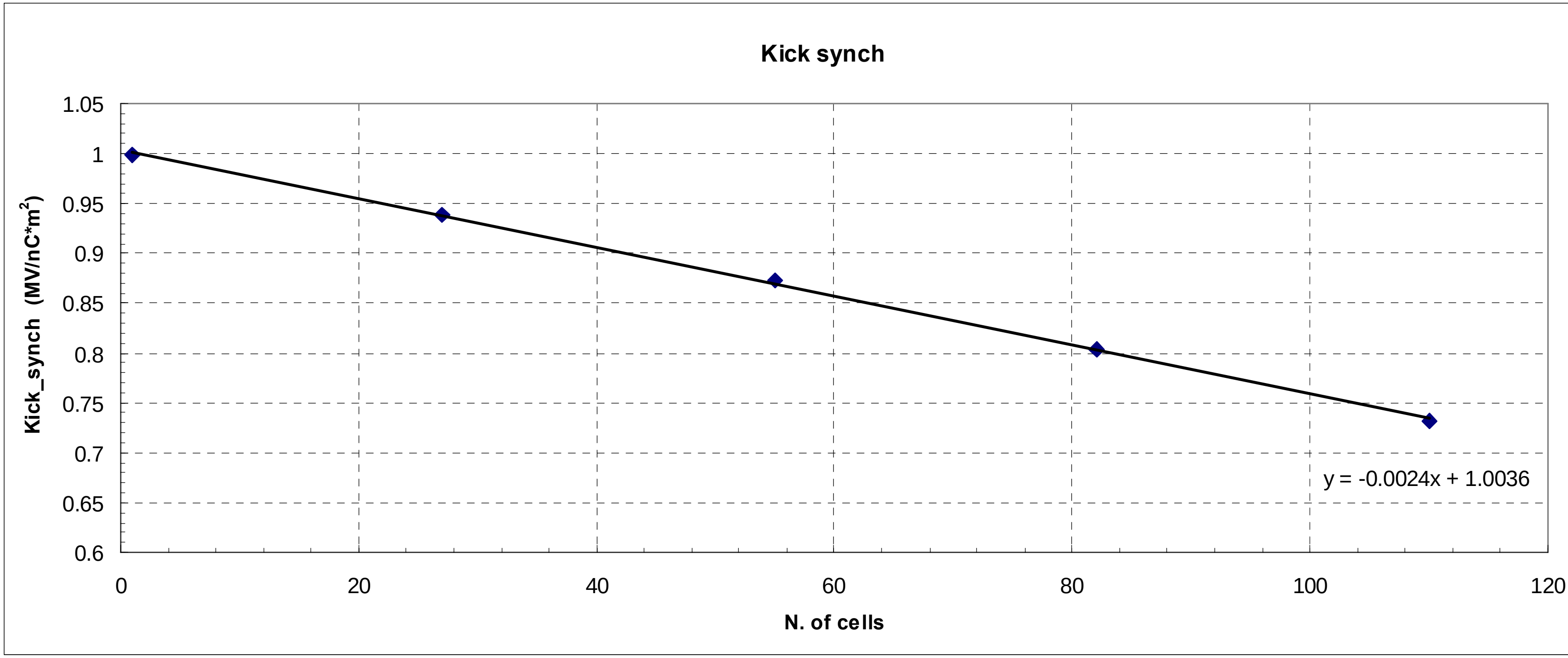


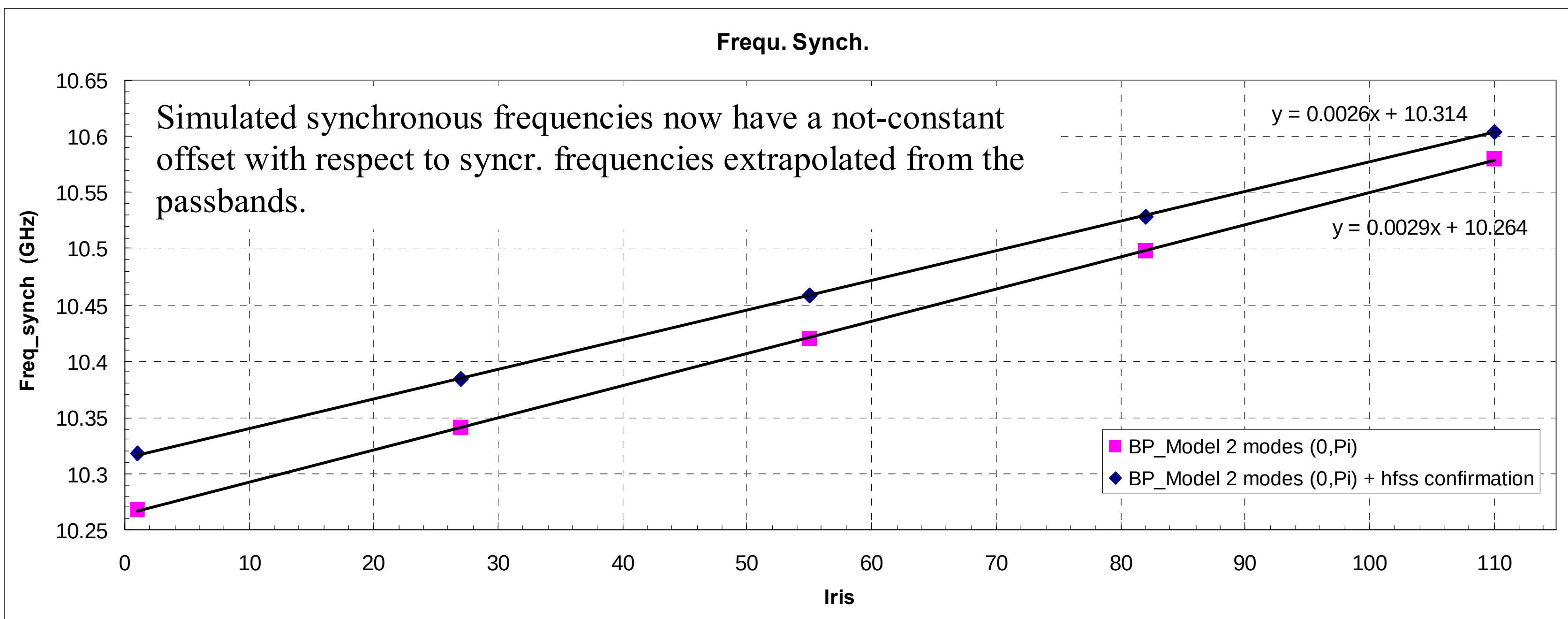


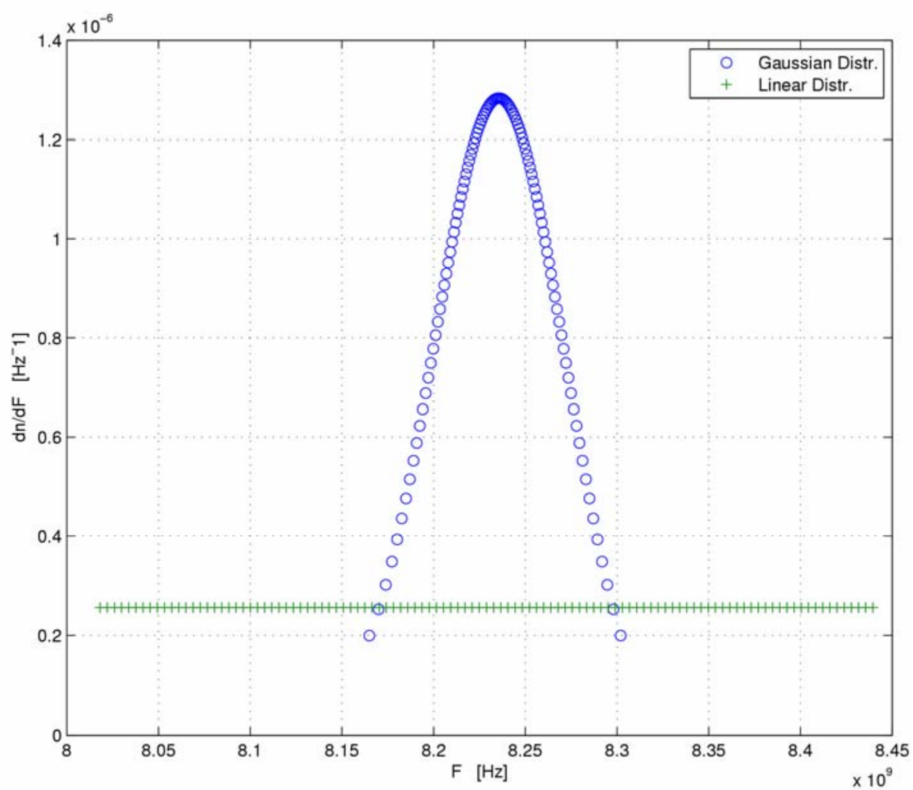
Synchronous frequencies and phase advances:

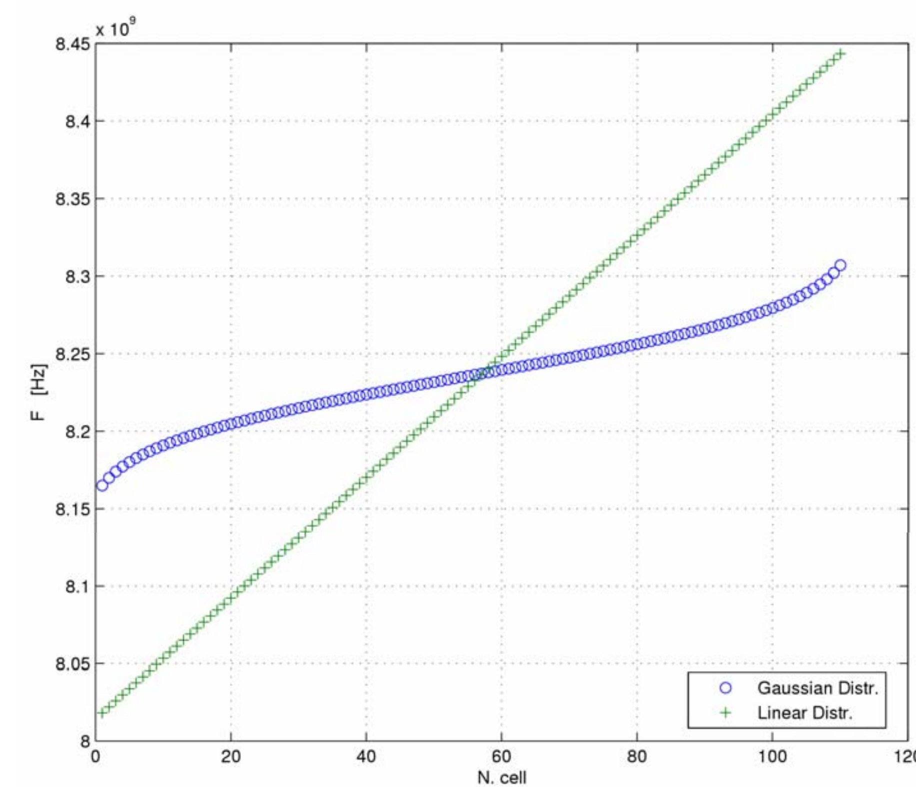
N. Cell	Freq. synch. (GHz)	phase Φ / 2π
1	10.26826258	0.400625
27	10.34078579	0.396875
55	10.42007228	0.391875
82	10.49742801	0.3875
110	10.57916576	0.3825

→ input for HFSS


Kick synch
Kick_synch (MV/nC*m^2)
N. of cells
y = -0.0024x + 1.0036


Frequ. Synch.
Simulated synchronous frequencies now have a not-constant offset with respect to syncr. frequencies extrapolated from the passbands.
y = 0.0026x + 10.314
y = 0.0029x + 10.264
Freq_synch (GHz)
Iris
BP_Model 2 modes (0,Pi)
BP_Model 2 modes (0,Pi) + hfss confirmation





Frequency Linear distribution:
(C-band present design, 1st Dipole band)

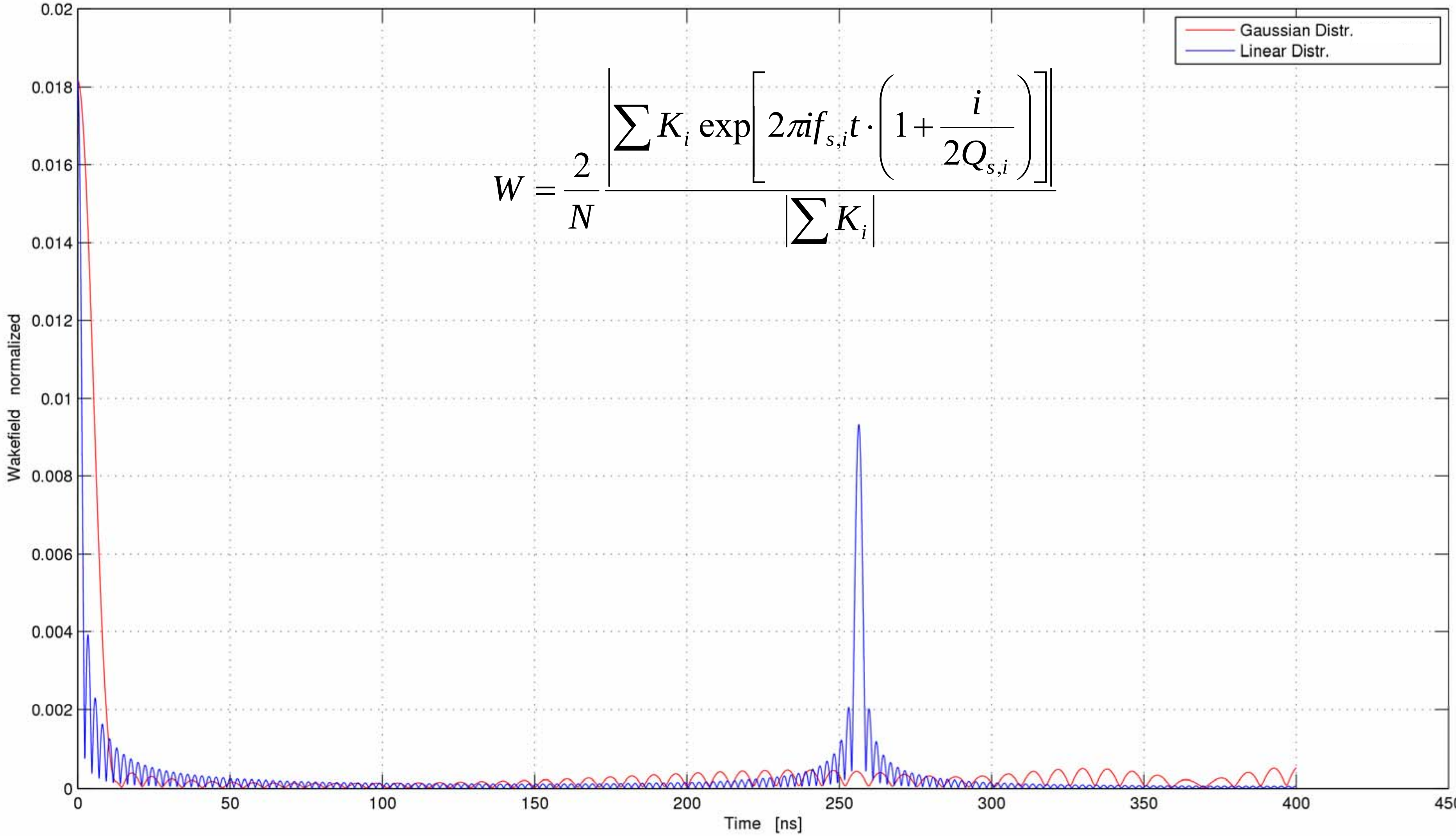
$f_s[GHz] = 0.0039n + 8.0143$ Total spread Δf_s: 425.3MHz n: 1…110

Frequency Gauss.-like detuned distribution:

Total spread Δf_s: 142 MHz σ: 142/4 MHz = 35.5 MHz

Spread period: 1/142 MHz ~ 7 ns (minimum bunch spacing)

For the both frequ. distributions, a same kick distribution (C-band present design) is used: $K_s[MV/nC \cdot m^2] = 0.0191n + 6.9385$



$$W = \frac{2}{N} \frac{\left| \sum K_i \exp\left[2\pi i f_{s,i} t \cdot \left(1 + \frac{i}{2Q_{s,i}} \right) \right] \right|}{\left| \sum K_i \right|}$$

Large flatness

1st D. band

2nd D. band

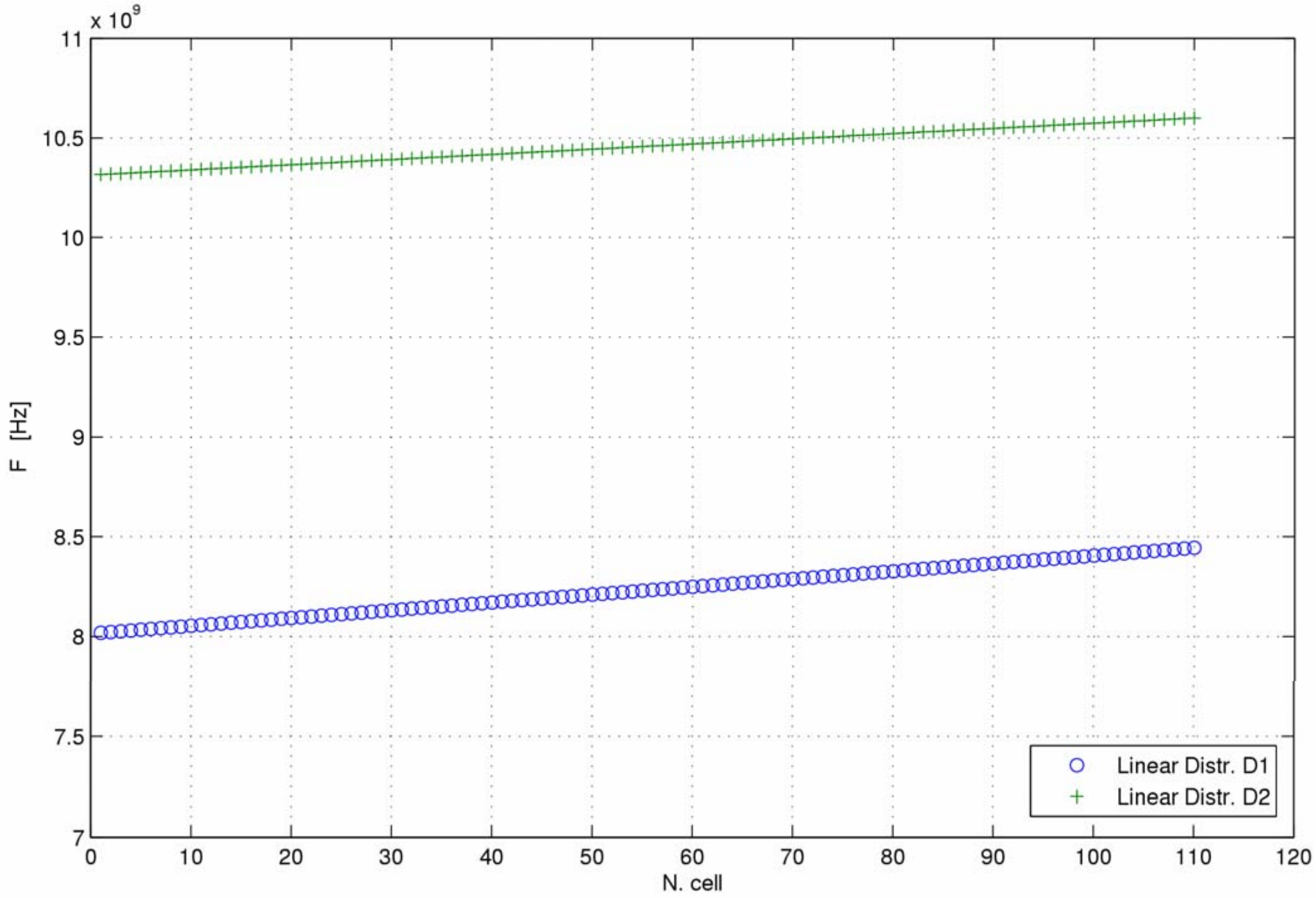
Frequency Linear distributions:

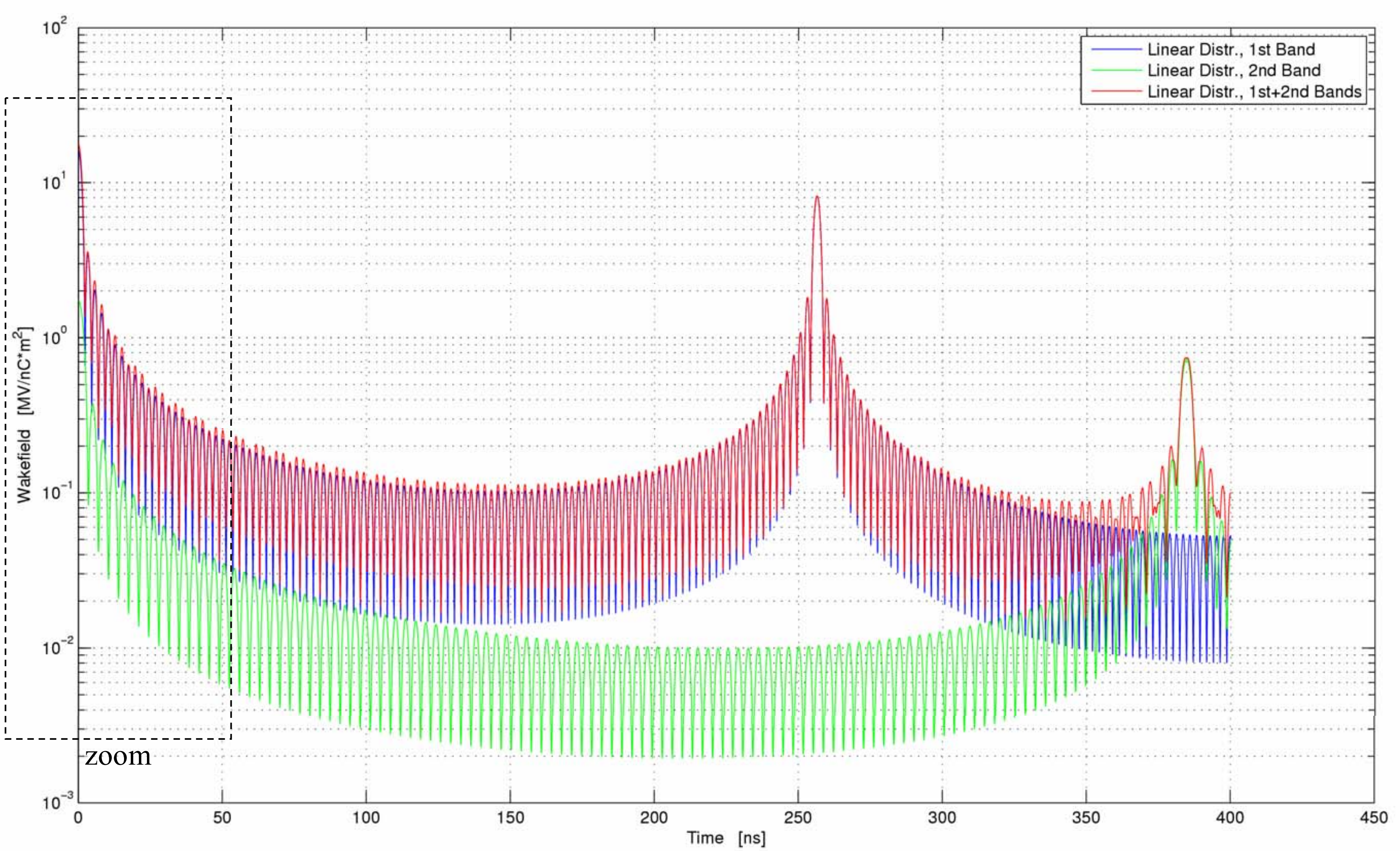
$$\begin{cases} f_s[GHz] = 0.0039n + 8.0143 \\ \text{Total spread } \Delta f_s\text{: } 425.3 \text{ MHz} \end{cases} , \quad \begin{cases} f_s[GHz] = 0.0026n + 10.314 \\ \text{Total spread } \Delta f_s\text{: } 287.2 \text{ MHz} \end{cases}$$

Kick distributions:

$$K_s[MV/nC \cdot m^2] = 0.0191n + 6.9385 \quad , \quad K_s[MV/nC \cdot m^2] = -0.0024n + 1.0036$$

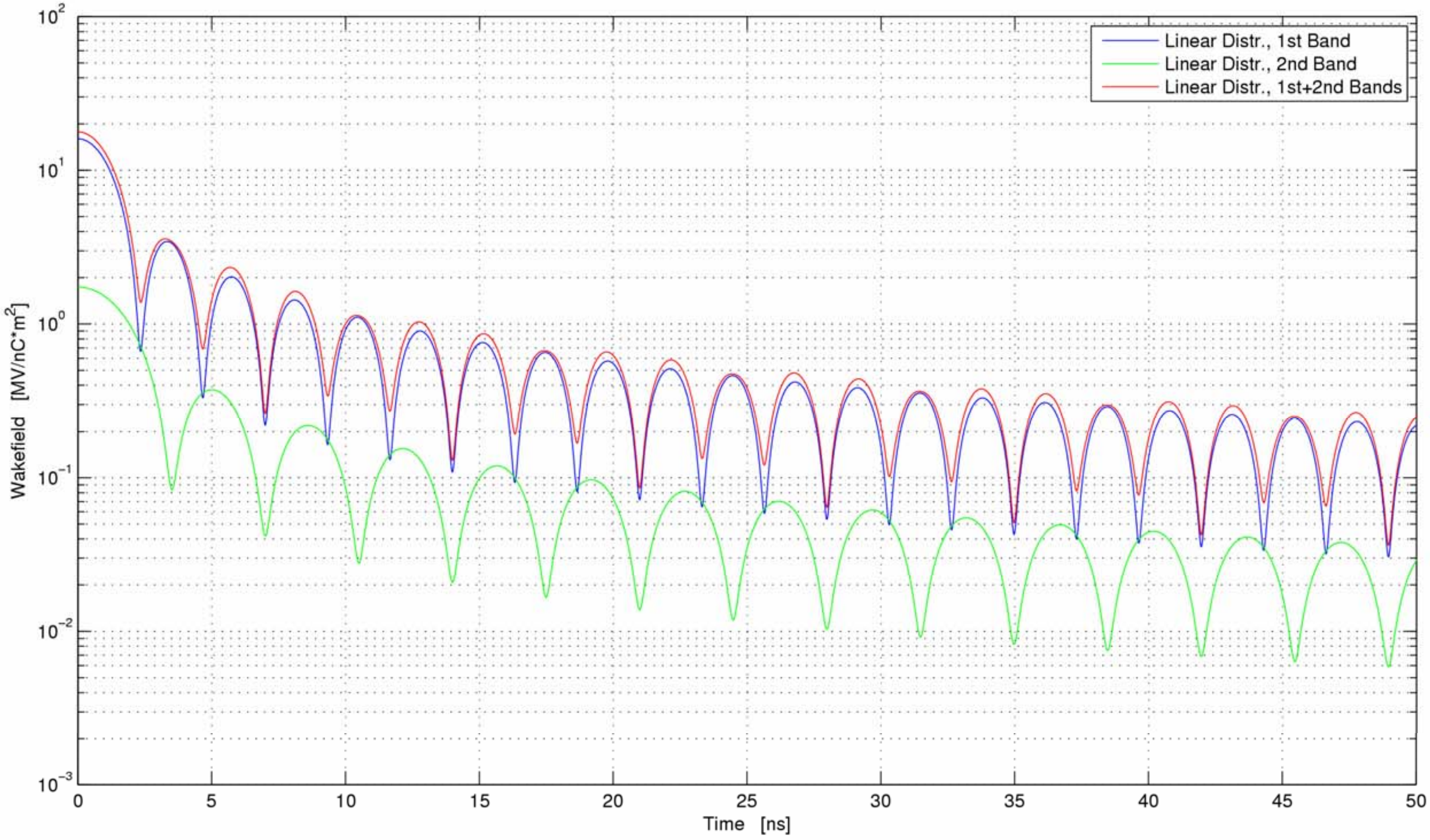
C-band present design: 1st, 2nd Dipole band





The wake sum is simply performed as the envelope sum $|W_{D1}| + |W_{D2}|$

Zoom 0-50 ns



Linear Distr., 1st Band
Linear Distr., 2nd Band
Linear Distr., 1st+2nd Bands
Wakefield [MV/nC*m^2]
Time [ns]
10^2
10^1
10^0
10^-1
10^-2
10^-3
0
5
10
15
20
25
30
35
40
45
50