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Orientation Power & Control

Diplôme 2012

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Intégration du système de mesure de foudre au Säntis avec un capteur de champ électrique installé par la HES-SO Valais

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Expert Dr Abraham Rubinstein

Sion, le 9 juillet 2012

☒ FSI ☐ FTV	Année académique / *Studienjahr* **2011/2012**	No TD / *Nr. DA* **pc/2012/40**
Mandant / *Auftraggeber* ☒ HES—SO Valais ☐ Industrie ☐ Etablissement partenaire *Partnerinstitution*	Etudiant / *Student* **Jérôme Lovey** Professeur / *Dozent* **Davide Pavanello**	Lieu d'exécution / *Ausführungsort* ☒ HES—SO Valais ☐ Industrie ☐ Etablissement partenaire *Partnerinstitution*
Travail confidentiel / *vertrauliche Arbeit* ☐ oui / ja [1] ☒ non / nein	Expert / *Experte* (données complètes) **Dr Abraham Rubinstein** Heig-vd | Rue Galilée 15 | 1400 Yverdon-les-Bains	

Titre / *Titel*

Intégration du système de mesure de foudre au Säntis avec un capteur de champ électrique installé par la HES-SO Valais

Description et Objectifs / *Beschreibung und Ziele*

Le travail proposé consiste à intégrer l'installation de mesure de foudre existante au mont Säntis avec une mesure de champ électrique (électrostatique proche ou électrique vertical rayonné à grande distance de la tour).

Au terme du travail, l'étudiant devra avoir réalisé les points suivants :

- Simulations approfondies avec Comsol sur la base des informations préliminaires obtenues durant le PrS
- Mise en forme des résultats de simulation pour être soumis à l'exploitant de la tour (Swisscom mobile)
- Choix du type de capteur (électrostatique ou électrique vertical rapide) et du modèle le plus approprié
- Achat / réalisation en atelier du capteur et de l'électronique annexe
- Ecriture d'une routine de contrôle et acquisition de données à distance du capteur
- Test du matériel en laboratoire
- Installation du capteur (si possible au Säntis)
- Documentation détaillée.

Délais / *Termine*

Attribution du thème / *Ausgabe des Auftrags:* 14.05.2012	Exposition publique / *Ausstellung Diplomarbeiten:* 31.08.2012
Remise du rapport / *Abgabe des Schlussberichts:* 09.07.2012 | 12h00	Défense orale / *Mündliche Verteidigung:* 10.09.2012

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Installation d'un moulin à champ électrostatique

Diplômant/e Jérôme Lovey

Travail de diplôme
| édition 2012 |

Filière
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Domaine d'application
Power & Control

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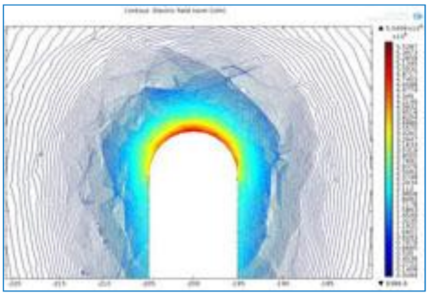
Objectif du projet

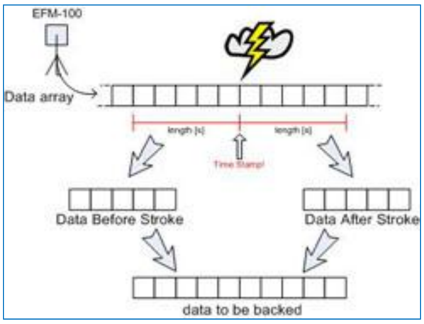
Ce projet a pour but d'intégrer un capteur de champ électrostatique à l'installation de mesure de signaux de foudre en opération au Mont Säntis. Cette installation, conçue à des fins de recherche, pourra aussi servir d'outil d'alerte pour orage imminent.

Méthodes | Expériences | Résultats

Plusieurs scénarios ont été simulés au moyen du programme de modélisation « Comsol Multiphysics », afin de permettre le choix d'un capteur existant sur le marché et définir l'emplacement le plus adéquat à son installation sur le site du Säntis. Sur la base de ces simulations, un capteur a été sélectionné et son emplacement a été fixé à proximité de la base de la tour.
Une fois le choix du capteur effectué, la deuxième étape du projet consistait en l'assemblage d'une station d'enregistrement des données de champ électrostatique provenant du moulin, constituée par un ordinateur sur lequel tourne une routine programmée en LabVIEW. L'enregistrement de ces données permet d'un côté (grâce à une carte GPS installée dans le PC) d'associer la signature électrostatique d'un impact de foudre sur la tour avec celle du courant qui y est injecté et, d'un autre côté, de générer une alarme d'orage approchant le Mont Säntis.
Les données enregistrées seront ensuite accessibles à distance depuis la Hes-so Valais Wallis au moyen d'un routeur internet.



Simulation de la composante verticale du champ électrostatique au sommet de la tour avec Comsol Multiphysics.



Représentation du fonctionnement de la récupération des données de la routine LabVIEW.

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Table des matières

1. Introduction

Une équipe de chercheurs de l'EPFL et de l'Heig-Vd a mis sur pied un projet de mesure de signaux orageux au Säntis. Ce projet consiste à enregistrer les impacts de foudre qui frappent régulièrement l'antenne Swisscom situé au sommet de la montagne, afin de mieux comprendre la physique du phénomène. Le site du Säntis a été choisi car, selon les statistiques de l'organisme européen de détection des éclairs, ce serait l'endroit d'Europe le plus touché par la foudre. Actuellement, l'installation en place est dépourvue d'appareillage capable de mesurer le champ électrostatique.

Le champ électrique peut être décrit comme le champ vectoriel résultant entre des particules électriquement chargées. On parle de champ électrostatique lorsque les charges qui sont à l'origine du champ sont fixes dans le référentiel.

Lorsqu'un nuage électriquement chargé se forme, un champ électrostatique se crée entre le sol et le nuage. Si la valeur de ce champ se situe généralement entre 10 et 20 kV/m, en fonction de la nature du terrain le champ peut notamment atteindre, au voisinage des pointes (arbre, montagne, antenne, clocher,…) des valeurs de l'ordre de 100kV/m voire plus.

Un moulin à champ électrostatique permet de connaître la valeur de ce champ et par conséquent, signaler une situation de risque d'impact de foudre imminent.

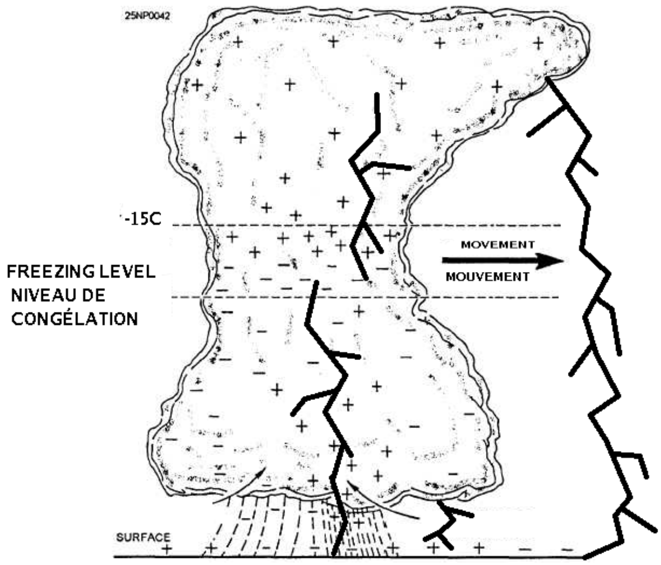


Figure 1 - Nuage orageux avec représentation des lignes de champ entre sa base et le sol [1]

1.1 Objectif du projet

Ce travail a pour but l'installation d'un moulin à champ à proximité de la tour du Säntis pour obtenir la mesure du champ électrostatique ambiant. Les données de ce nouvel appareil feront l'objet d'études visant à mieux cerner la foudre et les phénomènes physiques qui s'y rapportent. Elles seront également utilisées dans le but de mettre au point un système d'alarme qui devra assurer la protection des opérateurs de la tour.

Actuellement, un système d'alarme en cas d'orage, basé sur les données météorologique obtenues en temps réels par un système de localisation de foudre est déjà opérationnel. Mais la prestation de ce service coûte très cher aux exploitants de la tour. L'idée de ce projet est d'obtenir l'autorisation d'installer le moulin au sommet de la tour, ou dans sa proximité (voir objectifs scientifiques plus bas) et, en échange, de fournir un service d'alarme en cas d'orage à un prix raisonnable.

D'un point de vue scientifique, il serait extrêmement intéressant de mesurer le champ électrostatique au sommet de la tour ou, du moins, à proximité du point d'impact. Cela permettrait de mieux comprendre les mécanismes d'attachement de la foudre et donner d'importantes indications aux projets de systèmes de protection.

2. Moulin à Champ électrostatique

Les éléments fondamentaux d'un moulin à champ sont les suivants :

- Un moteur
- Un obturateur
- Une électrode
- Un circuit électronique de conditionnement du signal

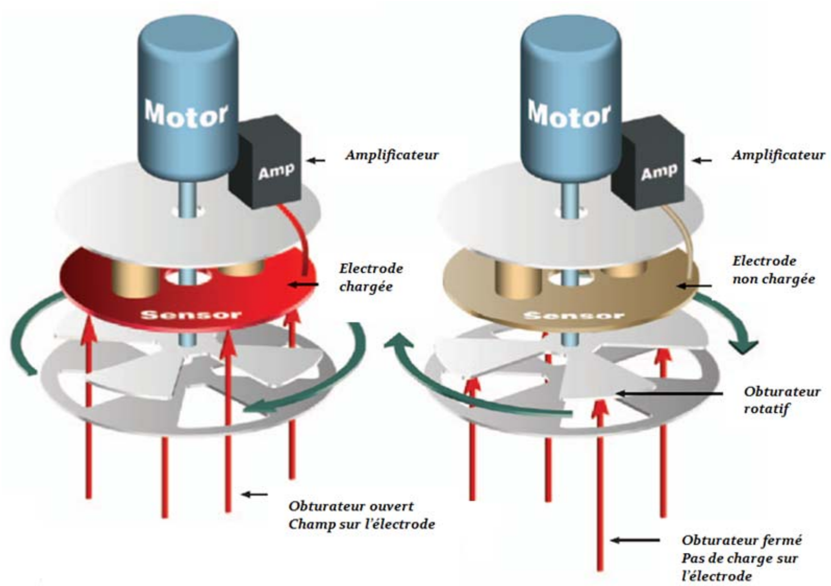


Figure 2 - Fonctionnement d'un moulin à champ [2]

Le signal du champ électrostatique est perçu par l'électrode. Il est alternativement masqué et exposé à l'électrode avec la rotation de l'obturateur et l'on obtient ainsi une tension alternative, sur l'électrode, que l'on peut facilement amplifier et mesurer au moyen d'un circuit électronique.

Conformément au circuit suivant, le signal perçu par l'électrode est amplifié, redressé, filtré puis envoyé sur les sorties de l'appareil. Cela dépend du fabricant mais dans le cas de la Figure 3, avec le moulin à champ électrostatique EFM-100 de l'entreprise Boltek on disposerait d'une sortie analogique et d'une sortie digitale sur fibre optique.

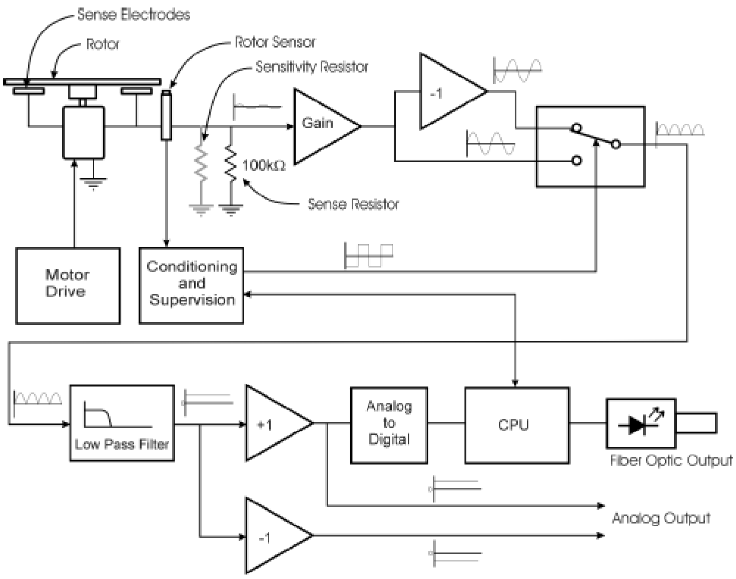


Figure 3 - Circuit électronique de l'EFM-100 [3]

3. Système actuel

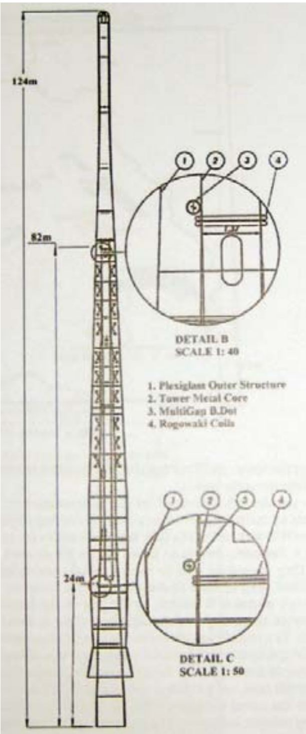
Les scientifiques qui travaillent sur le projet du Säntis ont déjà installé dans la tour un capteur de courant et un capteur de champ électromagnétique à 82m ainsi que deux capteurs de courant à 24m. (hauteurs relatives à la base de la tour)

Les données mesurées par ces capteurs sont de type analogique. La transformation analogique-numérique est effectuée avec le convertisseur LTX5515 de Terahertztechnologies et les données sont ensuite transmises par fibre optique au local de contrôle distant d'une cinquantaine de mètres de la base de la tour.

Un contrôleur, le National Instruments Compact Rio-9012 est également installé dans l'antenne et relié à la salle de contrôle par fibre optique. Il est programmé en LabVIEW et permet d'analyser les données enregistrées par les différents capteurs.

Dans la salle de contrôle les ordinateurs sont reliés sur un serveur et un routeur permet de piloter à distance l'installation.

Figure 4 - Positionnement des instruments dans la tour [4]



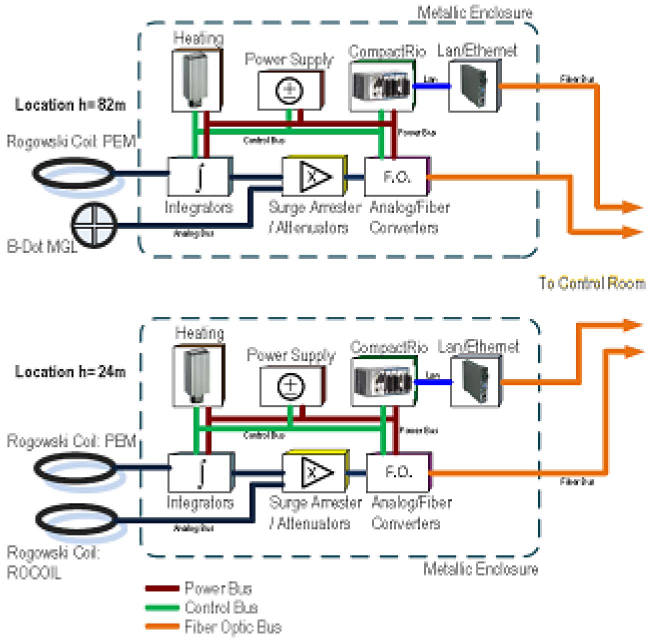


Figure 5 - Equipement dans la tour [3]

Deux antennes GPS sont également installées sur le site et reliées par câble coaxial à la salle de contrôle. Le but de ces antennes est de synchroniser les mesures avec les enregistrements obtenus par le système de détection de foudre.

Après visite sur place, il semblerait que le meilleur point retenu pour l'installation du moulin soit le sommet de la tour, mais à l'intérieur du radome ce revêtement présente l'avantage de protéger le moulin des caprices de la météo tout en étant transparent aux champs électrique et magnétique. L'installation sous la coupole ne serait pas la plus idéale à cause du revêtement en béton de la toiture qui va avoir une influence indéterminée sur la mesure du champ. Il est également impossible de l'installer à l'extérieur à cause des importantes chutes de neige en hiver.

Figure 6 - Antenne Swisscom Mont Säntis 2502m

4. Simulation

A l'aide du logiciel COMSOL Multiphysics, on a pu obtenir une première indication sur l'amplitude du champ électrostatique à proximité de la tour lors du passage d'un nuage chargé électriquement, afin de déterminer quelle plage dynamique le moulin devrait être capable de mesurer.

4.1 Conception du modèle de base

Pour obtenir une simulation la plus représentative possible de la réalité une interpolation du terrain a été reproduite, un cylindre est placé au sommet de la montagne pour représenter la tour et deux sphères, une chargée négativement et l'autre positivement, représentent le nuage.

Cette méthode pour modéliser le nuage m'a été suggérée par M. Alexander Smorgonskiy doctorant à l'EPFL, qui avait déjà dû effectuer une simulation similaire pour le Mont Gaisberg en Autriche. De mon côté j'ai cherché s'il n'existait pas un modèle de nuage tout fait dans COMSOL Multiphysics ou sur internet mais sans succès.

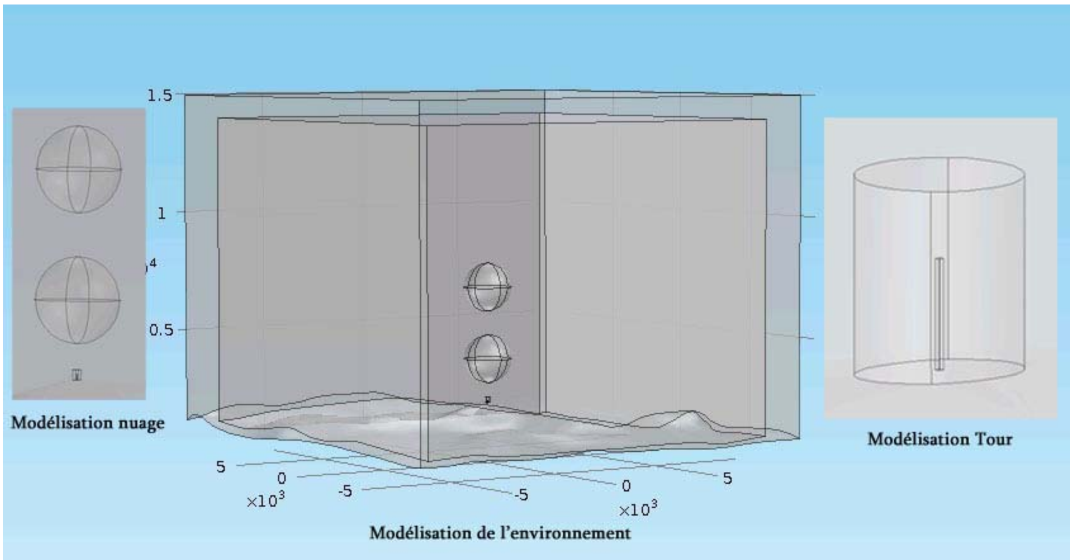


Figure 7 - Modèle comsol pour la simulation

Concernant l'interpolation du terrain, les données géographiques ont été téléchargée avec CGIAR-CSI SRTM digital elevation data (DEM). Cette plateforme permet de choisir des portions de terrain sur la carte du monde et d'obtenir ces données sous forme de fichier txt que l'on peut importer sur COMSOL Multiphysics. L'image ci-dessous illustre les données obtenues par SRTM digital elevation data (DEM), le terrain est représenté par des coordonnées en x,y et z.

Pour obtenir une simulation du champ électrostatique une fois le modèle terminé, il faut déterminer la ligne de champ sur laquelle les mesures doivent être prélevées de la simulation. Comme illustré dans la Figure 8 pour les valeurs du Tableau 1.

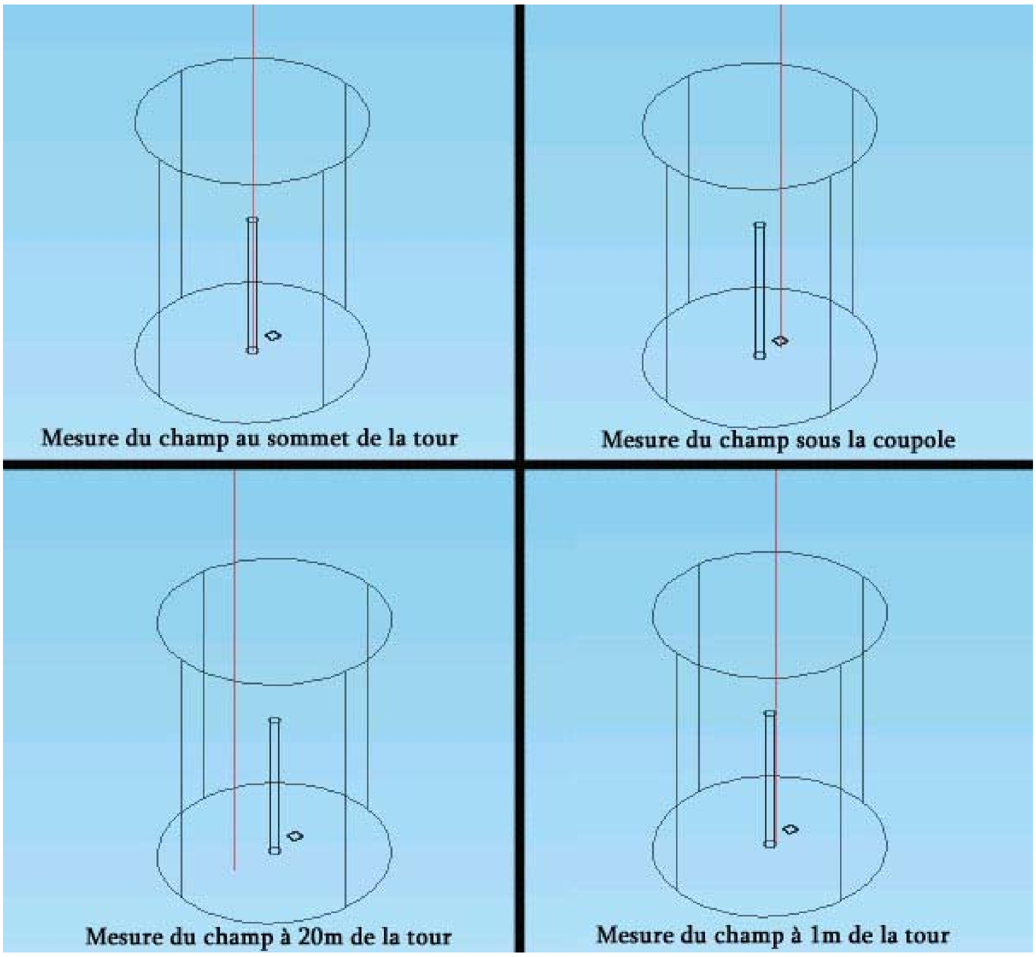


Figure 8 - Illustration de la ligne de mesure dans Comsol Multiphysics

Il reste deux inconnus concernant la simulation :

-la charge dans le nuage

-la hauteur entre la tour et le nuage.

Concernant la charge du nuage, je me suis appuyé sur les résultats des mesures effectuées sur place par les instruments installés par l'équipe de l'EPFL-Heig-VD. Le tableau 1 représente le champ électrique pour la charge de 95, 90 et 50% des 167 impacts de foudre enregistrés entre mai 2010 et janvier 2012 par les installations sur place, à différentes hauteurs de nuage d'après une conversation avec un chercheur de l'équipe de l'EPFL.

4.2 Résultats des simulations

Emplacement	Sommet de la tour			
H Tour-nuage	700m	2000m	3000m	6000m
95% (36.3C)	3E+03	900	500	60
90% (26.2C)	2E+03	600	300	50
50% (6.5C)	500	200	80	10

Emplacement	A 1m de la tour			
H Tour-nuage	700m	2000m	3000m	6000m
95% (36.3C)	500	200	80	20
90% (26.2C)	400	100	60	10
50% (6.5C)	90	30	20	4

Emplacement	A 20m de la tour			
H Tour-nuage	700m	2000m	3000m	6000m
95% (36.3C)	130	42	22	5.2
90% (26.2C)	95	31	16	3.8
50% (6.5C)	23.5	7.6	4	0.92

Emplacement	A 20 m de la tour sous 10x10x0.5m de béton			
H Tour-nuage	700m	2000m	3000m	6000m
95% (36.3C)	122	39	20.5	4.8
90% (26.2C)	88	28	14.8	3.5
50% (6.5C)	22	7	3.7	0.86

Tableau 1 - Résultat des simulations de Comsol valeurs du champ en kV/m

Selon les résultats des simulations et la plage de mesure du moulin à champ CS110 de l'entreprise Campbell Scientific (voir Annexe 1), on pourrait éventuellement envisager une installation d'un CS110 sous la coupole. Mais le problème c'est que les résultats de cette simulation sont plutôt indicatifs car en réalité on ne dispose pas simplement d'une plaque de béton au-dessus du moulin mais il y a aussi le pilier central qui la soutient qui peut avoir une influence sur la mesure du champ, ce qui implique qu'on devra considérer un certain degré d'incertitude dans l'interprétation des résultats de la simulation.

Il reste néanmoins un dernier endroit qui a attiré notre intérêt, il s'agit de la base de la tour. Le champ y est forcément plus faible à cause de l'effet d'ombrage à proximité de la tour. En effet, comme on le constate dans la Figure 9, le champ électrique produit par la charge du nuage est dévié sur le sommet de la tour avant d'atteindre le sol. Ce qui implique que si un appareil de mesure de champ électrostatique est placé à proximité de la base de la tour, sa mesure sera influencée par la présence de l'édifice. Pour être plus précis, avec les couleurs des lignes de champ on peut voir qu'au sommet de la tour on est en présence d'un champ électrique d'environ 90kV/m alors qu'à sa base le champ électrique n'avoisine que les 5kV/m.

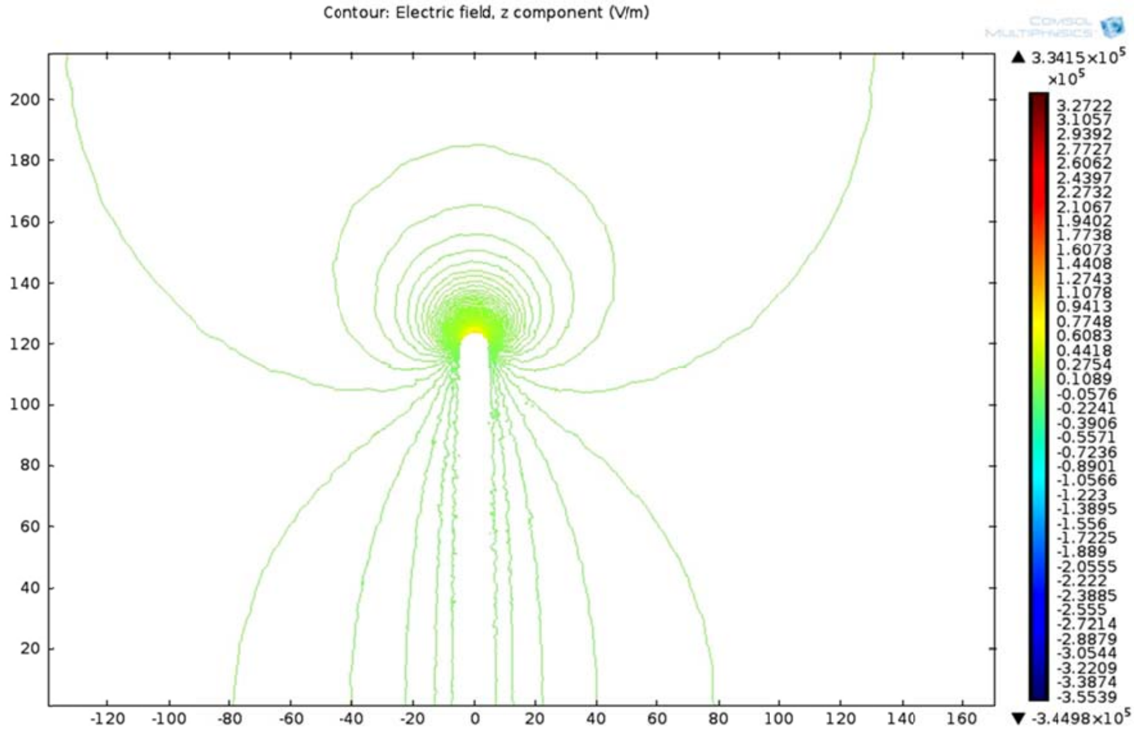


Figure 9 – Illustration du comportement du champ à proximité de la tour

Mais pour installer cet appareil à cet emplacement comme au sommet de la tour, il nous faudra obtenir d'une part une autorisation des exploitants de la tour et d'autre part, à cause des fortes radiations électromagnétiques dues aux antennes qui y sont en fonction l'accès y est encore plus restreint, un cours doit être suivi pour y pénétrer.

4.3 Etude de sensibilité du modèle

Afin de mieux comprendre l'influence qu'ont les divers éléments du modèle sur ces simulations, les paramètres suivants vont être étudiés séparément :

- Le relief
- La tour avec sommet plat
- La tour avec sommet arrondi

Il est possible que les résultats de la simulation soient sensiblement faussés par notre modèle. En effet, dans la simulation, la tour est modélisée par un simple cylindre alors qu'en réalité son sommet est sphérique. Dans notre cas, les angles abrupts du sommet du cylindre ont une influence sur la simulation du champ.

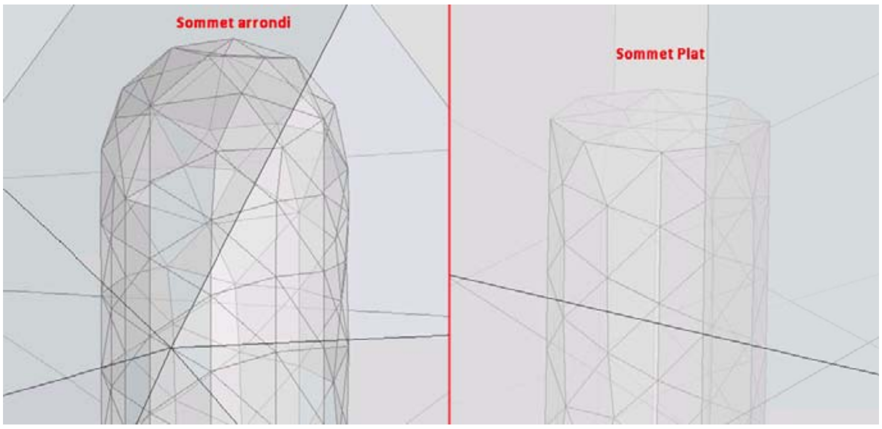


Figure 10 - Optimisation du sommet de la tour

Afin de vérifier la fiabilité des résultats obtenus avec ces simulations, quatre modèles de test ont été créés en faisant varier tour à tour les différents paramètres mentionnés précédemment. La Figure 11 représente ces quatre modèles. On dispose d'un premier modèle de référence avec simplement le nuage sans relief et sans tour, puis un modèle avec chaque paramètre.

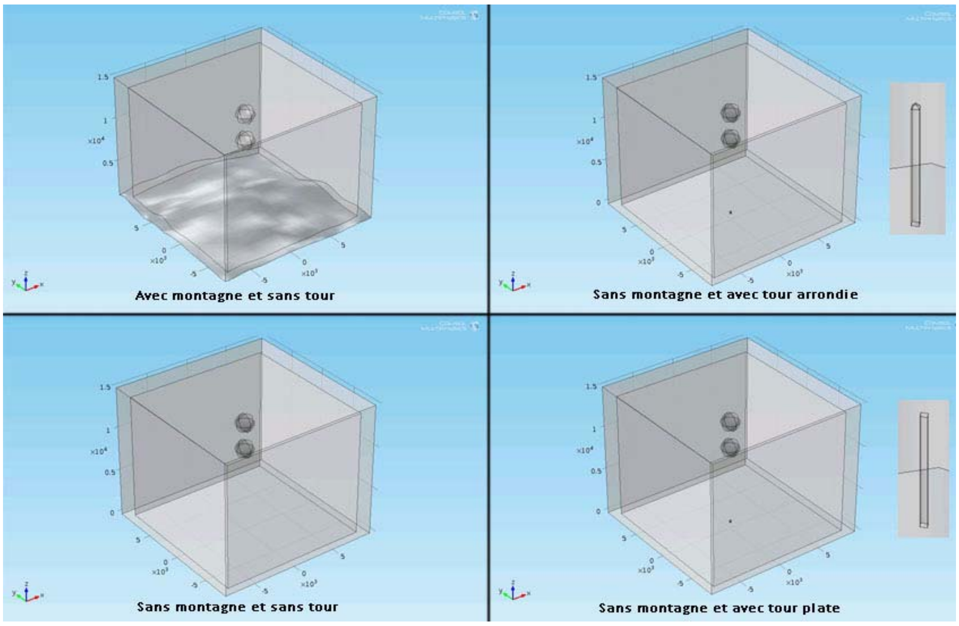


Figure 11 - Modèles de test

Pour cette phase de test, la hauteur du nuage est référencée à 8'000m en dessus du niveau de la mer et sa charge est fixée à 36.3C. A partir de là nous allons pouvoir évaluer l'influence du terrain et de la tour sur le champ électrostatique ambiant.

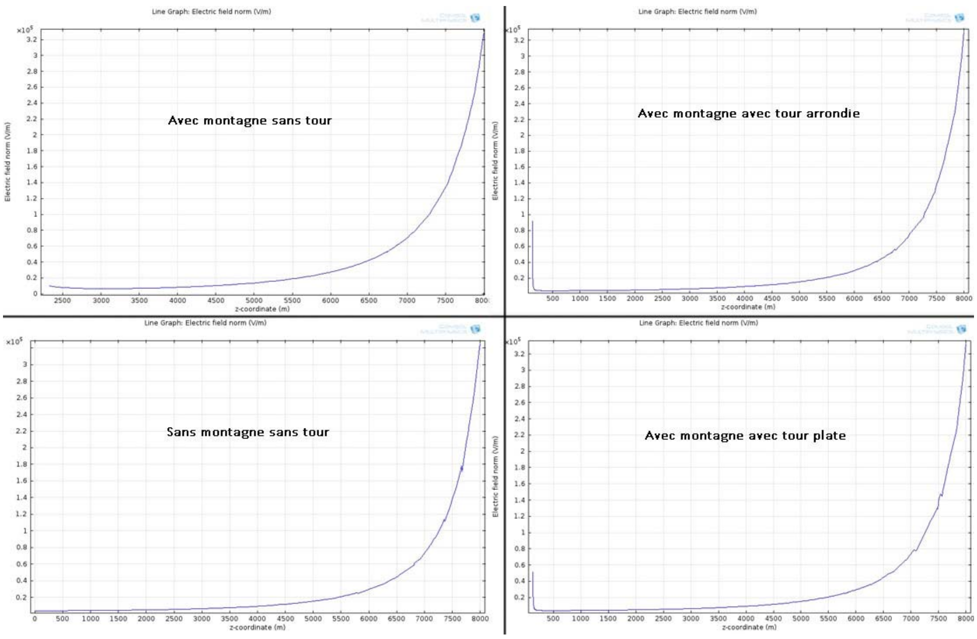


Figure 12 - Résultats des modèles de la figure précédente

Ces graphiques montrent qu'il y a très peu de changement dans le champ électrostatique sur la plus grande partie du chemin entre le nuage et le sommet de la tour. En effet ce n'est que lorsque l'on arrive au terrain que ces valeurs varient en fonctions des éléments qui s'y trouvent. Il apparaît ainsi que sur un sol parfaitement plat le champ atteindra 4kV/m. Ce résultat sur sol plat, fait office de référence pour les prochaines simulations en présence du relief ou de la tour.

Le constat est que 60% des 10 kV/m atteints lorsque l'on ajoute le relief sont dus à la montagne. Avec la tour au sommet plat, 92% des 50 kV/m relevés à son sommet sont dus à sa présence et l'effet de la tour au sommet arrondi concerne 95% des 90 kV/m prélevés à son sommet.

En outre, un travail concernant les solutions numériques de modèle de progression leader au moyen de la méthode des éléments finis (Annexe 3) fait mention d'une modélisation au moyen d'un disque chargé avec 4C, répartis uniformément sur sa surface, lequel est placé à 2000m au-dessus de la cible. Sur la base de ces informations, les modèles de la figure 11 ont été adaptés à ce système dans le but de vérifier ces résultats avec une autre méthode de modélisation. Selon les annexes 4a et 4b on constate qu'avec deux méthodes différentes pour la modélisation du nuage on obtient des résultats très proches, ce qui est encourageant en vue de l'installation du moulin sur le site du Säntis. Pour avoir une meilleure idée de la concordance de ces simulations avec la réalité, il faudra procéder à une étude des mesures du moulin à champ électrostatique une fois qu'il aura été installé sur place.

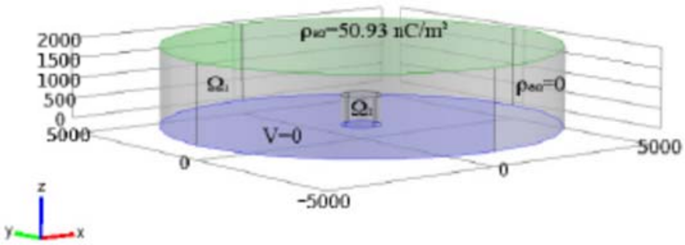


Figure 13 - Illustration du disque chargé [7]

A noter que dans les simulations, la mesure du champ est effectuée sur une ligne reliant le centre de la tour à la base du nuage (voir Figure 9). Avec l'illustration de la Figure 14 on peut clairement voir que le champ est plus faible au centre de la tour plate que sur les arêtes de son sommet, ce qui explique la différence de 40kV/m entre les deux modèles.

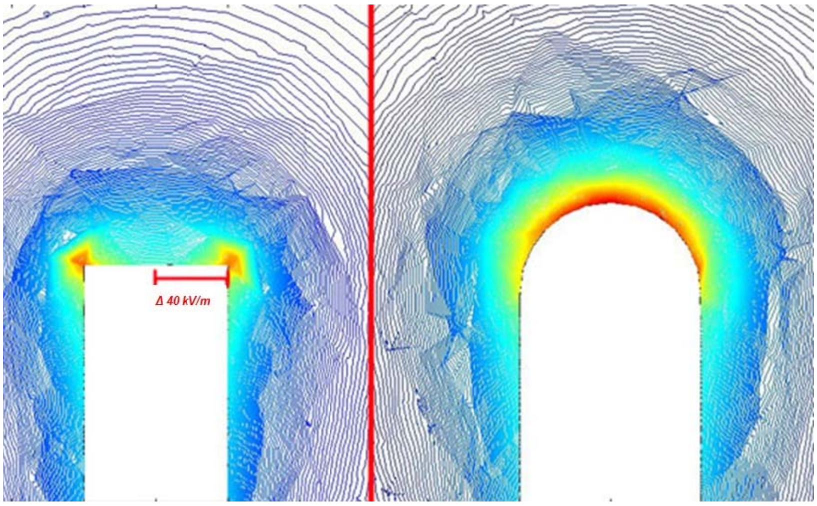


Figure 14 - Simulation du champ électrostatique au sommet de la tour

On peut donc en conclure sur la base de ces résultats que l'installation d'un moulin à champ électrostatique au Säntis est réalisable, néanmoins ces simulations nous donnent une idée quantitative de ce qui sera mesuré sur place mais cela devra être vérifié avec les mesures tirées du moulin une fois son installation réalisée. Toutefois, la hauteur du nuage à l'origine de ce champ électrostatique n'est pas constante d'un orage à un autre et les valeurs du champ pourraient dépasser les 220 kV/m au sommet de la tour. Si l'on se retrouve dans ce cas-là, d'un point de vue scientifique les choses deviendraient beaucoup moins intéressantes car les données acquises ne seraient pas du tout exploitables. En revanche les fabricants nous ont confirmé que leur moulins résisteraient sans dommage irréversible à une exposition de l'ordre du MV/m donc il est toujours possible d'envisager la création d'un système d'alarme fonctionnant sur la base de ces informations.

5. Recherche de matériel

5.1 Conditions locales

Il n'est pas évident de trouver sur le marché un appareil pouvant fonctionner sur le site du Säntis car on se trouve à 2502m d'altitude et les conditions météorologiques sur place sont relativement extrêmes tant au niveau de la température que de la météo.

Selon les données de Météo Suisse, la température la plus basse enregistrée est -26°C en 2001. Et en été la température moyenne maximale est de 7.7°C au mois d'août. Cette moyenne a été calculée au moyen des enregistrements de 1961 à 1990. On constate donc que les températures sont extrêmement basses sur place (Annexe 2).

Et concernant la météo, il est impossible d'installer un moulin à l'extérieur notamment à cause du vent pendant les orages mais aussi à cause des grosses quantités de neige en hiver.

Figure 15 - Aperçu de l'enneigement en hiver

5.2 Moulins à champ sur le marché

Les résultats de la recherche de moulins sont présentés dans le tableau ci-dessous :

	Fabricants	***Fournisseurs***	***Pays***	***Prix***	
EFM550	Vaisala	Kelag	Suisse	23'200.-	CHF
Zebra-2 Field Mill	Mission Instruments	Mission Instruments	Etats-Unis	3'882.-	CHF
EFS100	Mission Instruments	Mission Instruments	Etats-Unis	10'349.-	CHF
EFM-100 - 30m	Boltek	Space	France	2'048.-	CHF
EFM-100 - 45m	Boltek	Space	France	2'096.-	CHF
EFM-100 - 60m	Boltek	Space	France	2'181.-	CHF
CS110 EFM	Campbell Scientific	Campbell Scientific	France	5'053.-	CHF

Tableau 2 - Liste de moulins sur le marché

Dans le Tableau 2, seul deux moulins remplissent le cahier des charges en matière de résistance aux basses températures. Il s'agit de l'EFM-100 de Boltek et du CS110 de Campbell Scientific.

Cependant les valeurs du champ électrique que nous obtenons sur place avec la simulation peuvent être bien en dessus de la plage de mesure de nos moulins. On obtient au plus défavorable un champ de 2.6 MV/m au sommet de l'antenne. La plage de mesure de EFM-100 est de ±20 KV/m et celle du CS110 peut aller jusqu'à ±212 kV/m.

5.3 Installation du moulin

L'analyse des résultats des simulations met en évidence deux emplacements propices à l'installation du moulin :

1. *Au sommet de la tour*
2. *Sous la coupole*

5.3.1 Au sommet de la tour

En premier lieu, un CS110 serait installé au sommet de la tour car d'un point de vue scientifique il s'agit de l'endroit le plus intéressant du site.

Selon l'une ou l'autre des alternatives, les réalisations seront mise en place de deux manières différentes. Pour le CS110 au sommet de la tour il faudra compléter la liaison entre le moulin et le contrôleur Compact Rio et depuis là ce signal atteindra la salle de contrôle par les connexions existantes.

Pour limiter l'atténuation du signal et pour éviter tout problème d'interférence électromagnétique, la transmission entre le moulin et le contrôleur sera réalisée par fibre optique. Comme illustré à la Figure 16, la connexion au Compact Rio étant en RS232 pour établir cette liaison deux convertisseurs RS232/FO seront nécessaires.

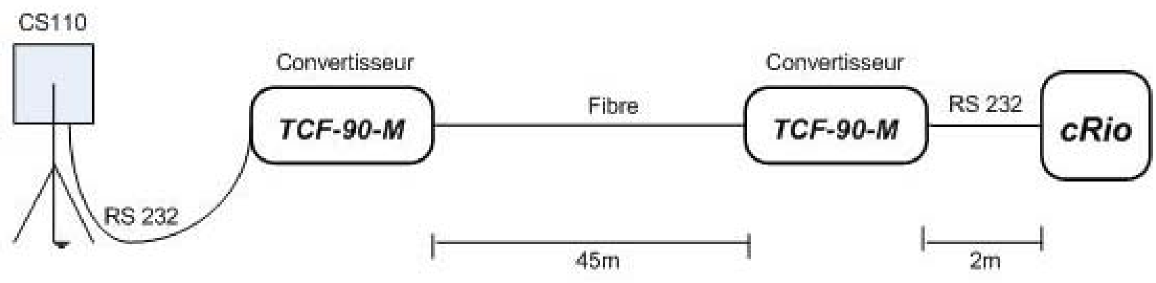


Figure 16 - Liaison du CS110 à la salle de contrôle

5.3.2 Sous la coupole

Si l'accès à la tour nous est refusé, l'idée serait de se replier sur l'installation d'un EFM-100 sous la coupole. Ce moulin possède une sortie FO et un convertisseur FO/RS23. Il nous sera donc possible de tirer la fibre depuis la coupole jusqu'à la salle de contrôle et de convertir le signal à ce moment pour relier le moulin au contrôleur. La longueur de câble nécessaire pour rallier la coupole à la salle de contrôle est de 65.6m. Elle a pu être mesurée sur un câble coaxial existant au moyen d'un TDR (Time Domain Reflectometer – appareil permettant de mesurer la longueur d'un câble coaxial au moyen d'une impulsion générée sur le câble à mesurer).

Boltek propose une offre comprenant un EFM-100 avec 60m de câble fibre optique une alimentation 230V monophasée avec un convertisseur EPM-1, un EFA-10 (convertisseur fibre/RS232), un câble USB, un câble RS232 ainsi qu'un logiciel de traitement des données exécutable sur Windows et les manuels de l'appareil.

Dans notre cas, les 60m de fibre ne suffisent pas à relier le moulin à la salle de contrôle. Mais Boltek, nous précise que les données de l'EFM-100 sont exploitables jusqu'à 300m de fibre optique dans notre cas on prend en considération la mesure effectuée avec le TDR plus 5m de réserve de chaque côté soit environ 75m de fibre.

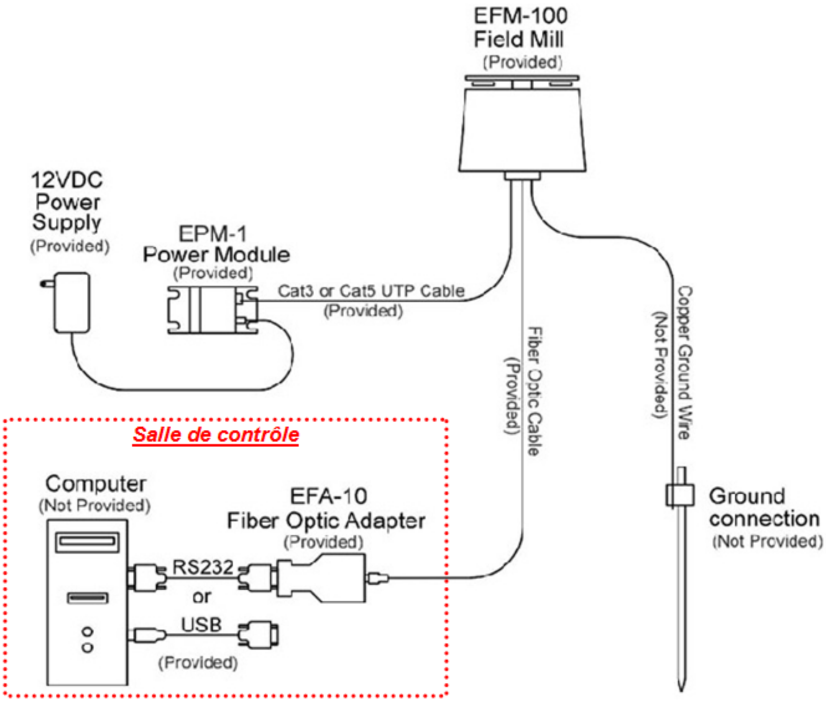


Figure 17 - Liaison de l'EFM-100 à la salle de contrôle [8]

5.4 Choix de l'emplacement et du mode d'installation

Dans les premiers temps de son installation le moulin fonctionnera de manière expérimentale, ses mesures seront donc examinées et comparées avec les simulations ou d'éventuelles données météorologiques afin d'attester de son bon fonctionnement et de la fiabilité du système d'alarme. Durant cette période, il faudra probablement procéder à quelques ajustements sur le moulin, compte tenu des difficultés d'accès à la tour et d'une information de Campbell scientific ne garantissant pas le fonctionnement de la centrale de mesure CR1000 intégrée au CS110 lors d'une installation à proximité de fortes radiations électromagnétiques, dans le cadre de ce travail le choix s'est porté sur l'installation d'un EFM-100 sous la coupole conformément au schéma de la Figure 17.

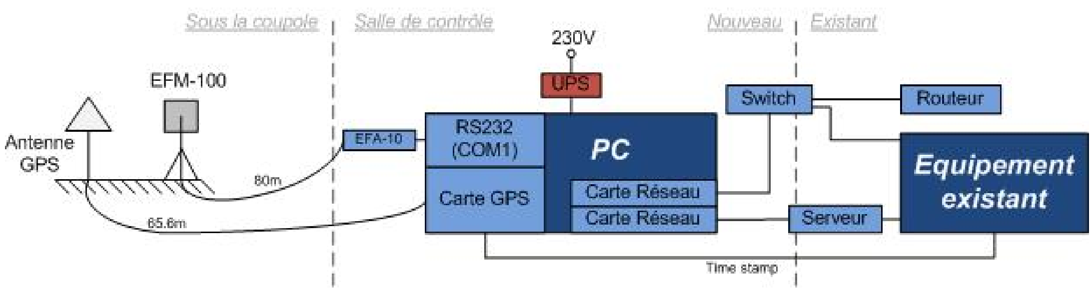


Figure 18 - Schéma bloc de l'installation

6. Programmation LabVIEW

L'EFM-100 envoie une trame numérique qui arrive au PC sur le port RS232. Le traitement de cette trame s'exécute ensuite avec le programme LabVIEW.

La trame est fractionnée bit par bit puis on isole les bits relatifs à la valeur du champ électrique pour réaliser un affichage graphique et gérer les alarmes.

En parallèle, toutes les trames sont stockées dans un tableau et elles seront enregistrées sur fichier 'txt' en cas d'impact de foudre.

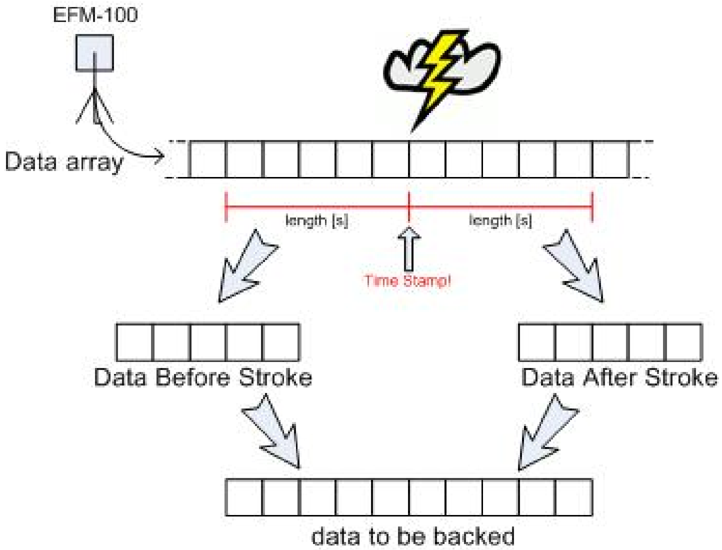


Figure 19 - Représentation du fonctionnement du programme d'acquisition

L'exécution de ce programme est expliquée ci-dessous en sept parties :

- Acquisition
- Traitement de la trame
- Affichage graphique
- Gestion des alarmes
- Sélection des données à sauvegarder
- Ecriture du fichier txt
- Front panel

6.1 Acquisition

La figure 20 illustre les trois blocs qui sont utilisés pour réaliser cette partie du programme. Dans le premier bloc, « VISA serial » on définit les caractéristiques de la trame d'entrée ainsi que l'interface physique qui reçoit les informations du moulin.

Visa resource name :	Sélection du port d'entrée	*Dans notre cas :* *COM1*
Baud Rate :	Spécification de la vitesse de transmission	*9600 baud*
Parity :	Etat du bit de parité 0, 1 ou rien	*none parity*
Data bits :	Nombre de bits de données de la trame	*8 bits*
Stop bit :	initialisation du bit d'arrêt	*1*

Dans le second bloc, « VISA R », on lit les informations qui arrivent sur la trame ; elles sont traitées plus loin dans le programme. « Byte count » définit le nombre de bytes à lire.

Et le troisième bloc « VISA C » a pour but de refermer le port sériel à la sortie de la boucle.

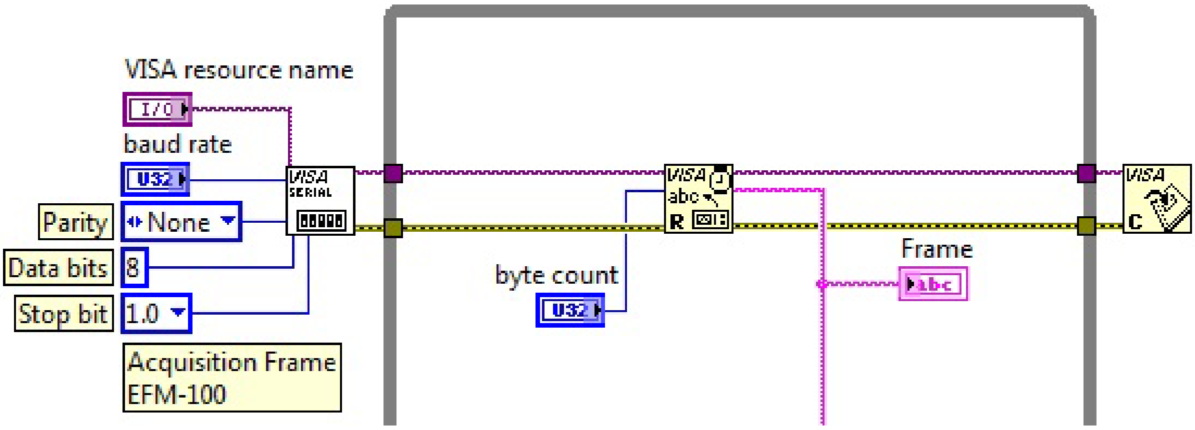


Figure 20 - Acquisition sérielle sur labVIW

6.2 Traitement de la trame

La trame que l'on reçoit du moulin est composée de la façon suivante :

$<S><EE.EE>,<F>*<C><CR><LF>

S correspond au signe du champ électrostatique, positif ou négatif, E se rapporte à la valeur du champ électrostatique mesuré, F indique une erreur du rotor et C est le checksum propre à la trame.

Exemple : $-00.68,0*D3
Avec une valeur de mesure du champ correspondant à -0.68kV/m avec aucune erreur du rotor.

6.2.1 Extraction des 9 premiers bits

Lorsqu'une trame arrive, elle est fractionnée bit par bit du '$' à '*'. Les neuf premiers bits sont ainsi séparés un à un comme on peut le voir dans la partie rose sur la gauche de la figure 21. Avec le premier bloc de cette séquence, on sélectionne le bit à isoler de la trame.

Le second bloc permet la conversion d'un String en tableau de décimal. Et dans le troisième bloc on transforme le tableau de décimal en décimal correspondant à la valeur ASCII du caractère extrait de la trame.

Pour les bits relatifs à une mesure du champ électrostatique (E), on soustrait ensuite la valeur ASCII du bit par 48 pour obtenir la valeur réelle du champ en décimal. Cette transformation est nécessaire puisque l'on ne peut pas créer un graphique de 'string' sur LabVIEW.

Exemple :

String	***décimal(ASCII Value)***	***Réelle (en décimal)***
E=0	E=48	E=48-48=0
E=6	E=54	E=54-48=6

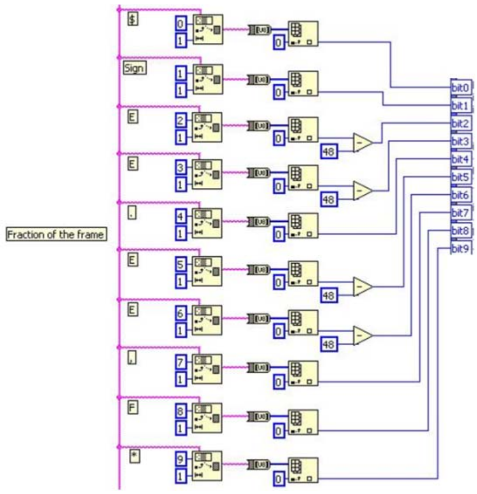


Figure 21 - Fragmentation de la trame du Moulin

6.2.2 Concaténation des bits du champ

Une fois les bits de la trame isolés, ils sont récupérés et traités au moyen de quelques lignes de code dans un noeud de formule LabVIEW.

On teste ensuite le bit de signe et on calcule la valeur du champ électrostatique de la manière suivante :

Bit2*10000
Bit1*1000
Bit5*100
Bit6*10

} et on somme ces résultats pour obtenir une valeur du champ en [V/m]

Cette valeur est stockée dans la variable 'E_Field' qui est réécrite à l'arrivée de chaque trame. A noter que si l'on désire afficher une valeur du champ électrostatique en [kV/m] dans le graphique il suffit de diviser par 1000 les facteurs de multiplication des bits dans le nœud de formule de la figure 22.

On profite également de l'éclatement de la trame pour allumer un voyant lumineux sur le contrôle panel lors d'un problème du rotor.

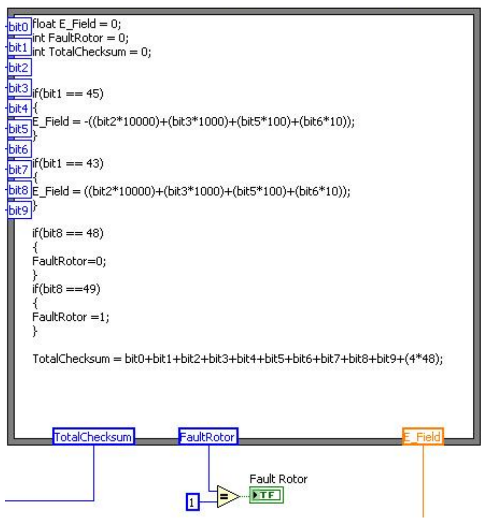


Figure 22 - Concaténation du champ et calcul du checksum

6.2.3 Contrôle checksum

Le checksum est obtenu en effectuant la somme des valeurs ASCII des bits 0 à 9 compris (TotalChecksum) et en effectuant ensuite le module de cette somme par 256. Le résultat du module est transposé en hexadécimal et placé en fin de trame.

Exemple :

	$	-	0	0	.	6	8	,	0	*		Total	Modulus of 467/256	Hex Value of the Remainder
ASCII Value:	36	45	48	48	46	54	56	44	48	42		467	211	D3

Figure 23 - Exemple de trame avec calcul checksum [9]

La valeur assignée à la variable 'TotalChechsum' dans la figure 22 correspond à la somme des bits 0 à 9. On effectue ensuite le module de 'TotalChecksum'/256 et on compare le résultat avec le checksum extrait de la trame. Si les résultats ne concordent pas on allume l'avertisseur 'Error Checksum' sur le front panel.

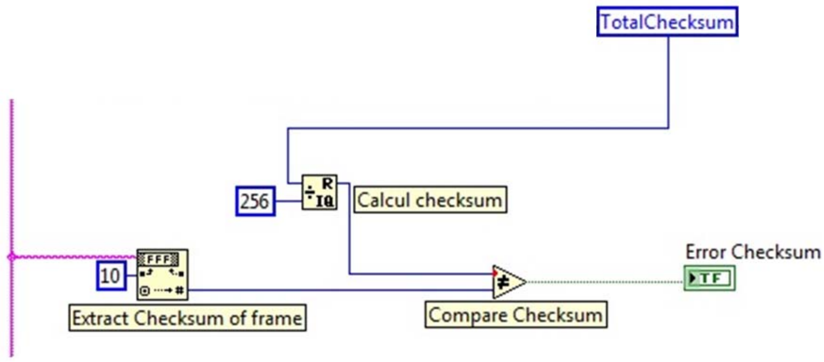


Figure 24 - Extraction et comparaison du checksum

6.3 Affichage Graphique

Pour réaliser un affichage graphique sur le front panel, on utilise le tableau 'Graph Array' à chaque exécution de la boucle on remplit une case avec la variable 'E_Field'. Ce tableau est utilisé sur un graphique du front panel.

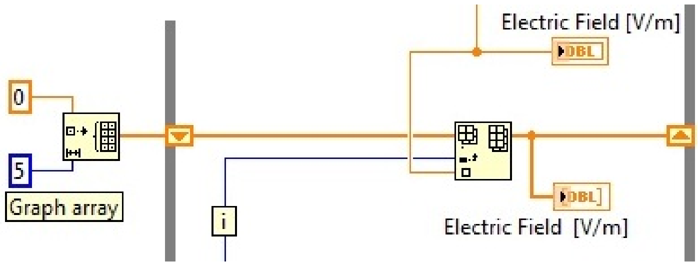


Figure 25 - Remplissage du Graph array

Actuellement deux graphiques figurent sur le contrôle panel, leur comportement à l'affichage des données diffère entre l'un ou l'autre. Comme il ne sert à rien d'avoir deux graphiques affichant la même chose, lorsque le moulin sera là, il faudra choisir lequel est le plus adapté à la situation et supprimer le second.

6.4 Gestion des alarmes

La gestion du système d'alarme pour la sécurité des opérateurs de la tour est effectuée dans le nœud de formule de la figure 26. En entrée on arrive avec la valeur du champ réelle en décimale et on effectue deux tests :

1. Si le champ est entre 1'000 et 10'000 ou entre -1'000 et -10'000 [V/m]

   ⇒ *Enclenche l'alarme jaune*

2. Si le champ est plus grand que 10'000 ou plus petit que -10'000 [V/m]

   ⇒ *Enclenche l'alarme rouge*

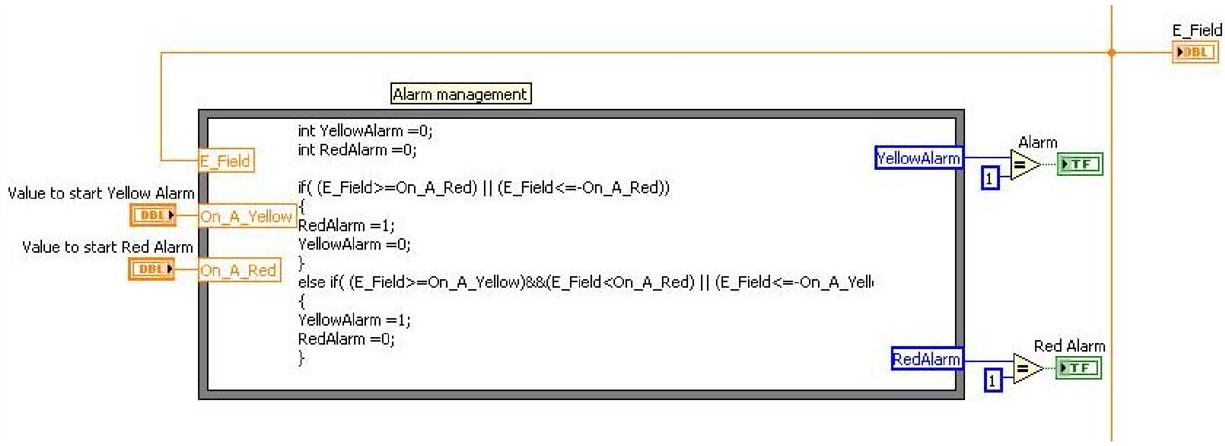


Figure 26 - Gestion des alarmes

Puisque à l'heure actuelle on ne sait pas trop dans quelle mesure les simulations du champ sous la plaque de béton sont fiables ou pas (Annexe 5), pour le moment les valeurs par défaut sont fixées à ces limites, mais durant la phase expérimentale il est toutefois possible de les ajuster sur le front panel au moyen de contrôleurs prévus à cet effet.

6.5 Sélection des données à enregistrer

6.5.1 Remplissage du Data array

Chaque trame arrivant par le port RS232 est stockée dans le tableau 'Data array' on incrémente la case du tableau dans laquelle sera écrite la trame avec l'itération de la boucle 'while' du programme. Les données déjà inscrites dans le tableau sont mémorisées au moyen d'un 'Shift Register' et ainsi sans interruption dans l'exécution du programme, le tableau se remplit à l'infini.

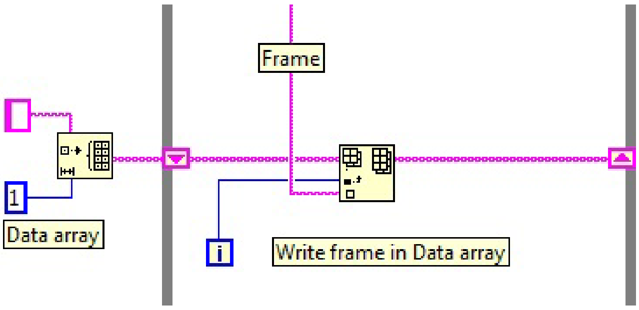


Figure 27 - Remplissage du Data array

6.5.2 Condition, événement et time stamp

On qualifie d'événement un impact de foudre sur la tour du Säntis. Lorsqu'un événement se produit, les sondes de rogowski installées sur l'antenne mesurent un courant. Au moment ou le numériseur de ces données se met en marche un timer génère une impulsion vers la carte GPS ce qui va permettre de congeler le temps (time stamp) afin de synchroniser les mesures des différents appareils installés sur place.

Cette impulsion sera également l'élément déclencheur de la sauvegarde des données du moulin à champ. Elle est simulée dans ce code par le bouton 'Digitizer Start'.

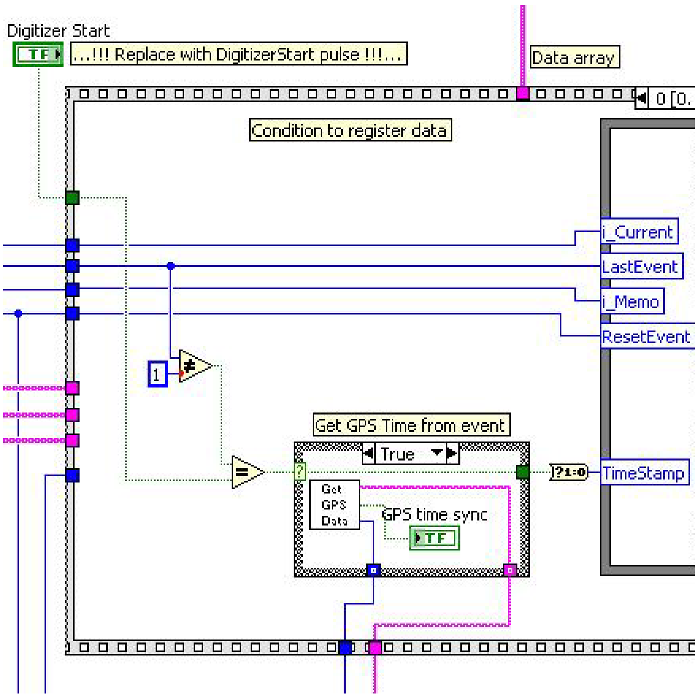


Figure 28 - Récupération du temps GPS lors d'un événement

Comme on peut le voir sur la figure 28, on sauvegarde les données GPS au moyen du bloc 'Get GPS Data'. Pour que le 'time stamp' ait lieu, il faut d'une part une impulsion du 'Start Digitizer' et d'autre part aucun évènement en cours d'enregistrement.

Dans notre cas, lorsqu'un événement se produit la partie 'Data Before Stroke' pourrait être exportée directement dans le fichier txt mais on attend que le tableau 'Data After Stroke' soit rempli pour exporter le tout d'un seul coup. Comme le signal du time stamp est une impulsion, pour permettre le remplissage du 'Data After Stroke' on a besoin d'une variable qui passe 1 lors d'un événement et qui est remise à 0 une fois le tableau rempli. C'est le but de la variable 'Event' de la figure 29. Lorsque le 'ResetEvent' passe à 1(voir point 6.3.4) la variable 'Event' est remise à zéro et le cycle pourra recommencer à la prochaine impulsion du time stamp.

Il est également indispensable de définir à partir de quelle case du 'Data array' les données doivent être transposées dans le 'Data After Array'. Comme les cases du 'Data array' correspondent aux itérations de la boucle, pour obtenir ce point de départ il suffit de mémoriser le 'i' de la boucle while au moment ou un événement survient. Ceci est réalisé au moyen de la variable 'i_Register' et d'un shift Register de labview. La valeur de i_Register passe par un shift register et revient sur i_Memo.

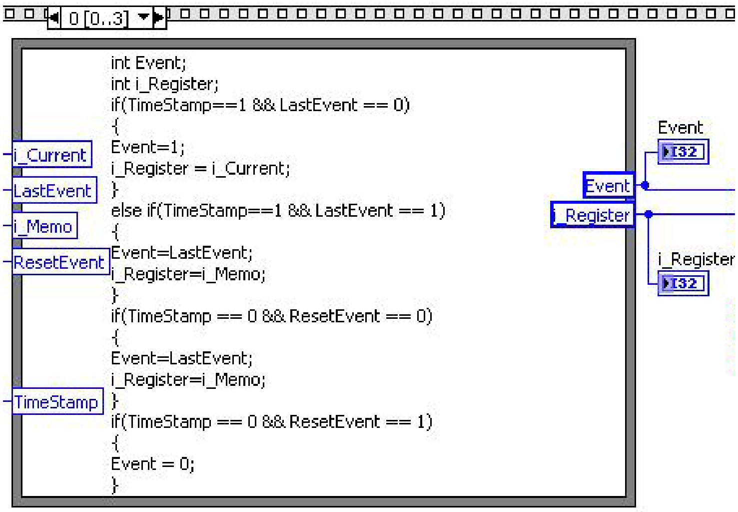


Figure 29 - Conditions pour lancer la sauvegarde des données

6.5.3 Extraction des données d'avant l'impact

La condition pour que le programme effectue une sauvegarde des données avant l'impact est l'impulsion du time stamp. 'length' est une variable qui peut être modifiée par l'utilisateur sur le front panel, elle fixe le nombre de données avant et après l'impact que l'on va écrire sur le fichier txt (voir figure 19). On définit l'emplacement le point de départ des données à prélever du 'Data array' en effectuant la soustraction de l'itération de la boucle while et du 'length'. Une fois les données inscrite dans le 'Data Before Array', elles sont conservée avec un shift register jusqu'à la fin du remplissage du 'Data After Array'.

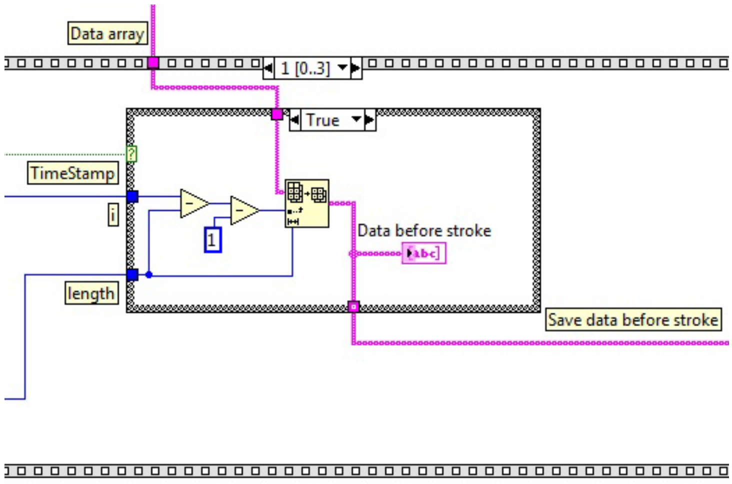


Figure 30 - Sauvegarde des données d'avant l'impact

6.5.4 Extraction des données d'après l'impact

L'élément déclencheur pour l'importation des données du 'Data After stroke' est le passage à 1 de la variable 'Event'. Ensuite on attend que sa taille ait atteint la longueur 'length' (*i_Memo+Length == i_Current*) et on envoie le tout dans un shift register pour récupérer les données à la boucle suivante dans le 'Array to save '.

Lorsque le 'Data After Stroke' est envoyé vers le shift register, l'afficheur de taille du tableau retourne une valeur quelconque. Si le test 'différent de 0' est positif cela indique que les données sont envoyées et le 'ResetEvent' passe à 1.

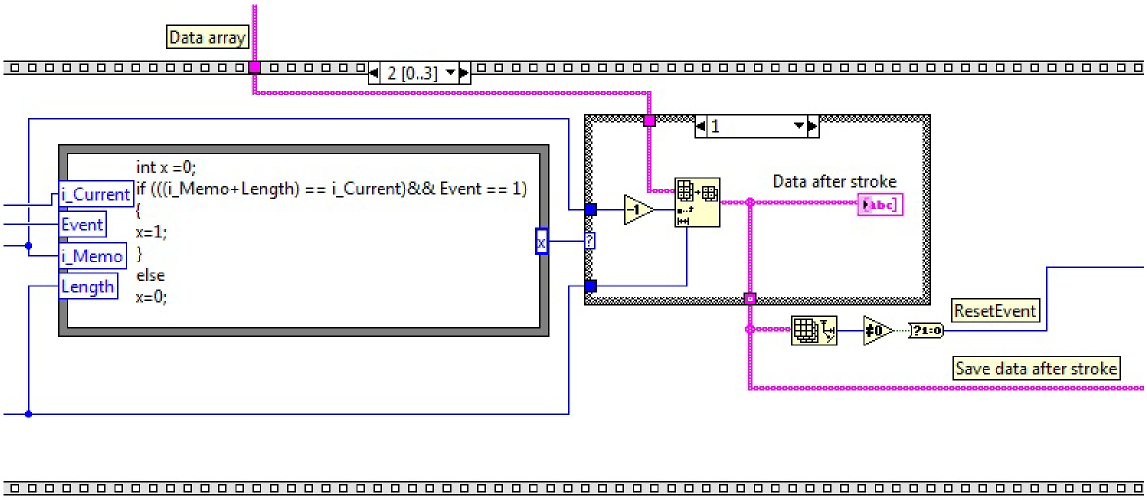


Figure 31 - Sauvegarde des données d'après l'impact

6.5.5 Remplissage du Array to save

La figure 26 représente le remplissage du 'Array to save', le tableau 'Data Before Stroke' est inséré à la case 0 et le 'Data After Stroke' est placé juste à la suite à la case désignée par la variable 'length'. A l'image du 'Data Array' le 'Array to save' continuera son remplissage tant que le programme tourne sans interruption.

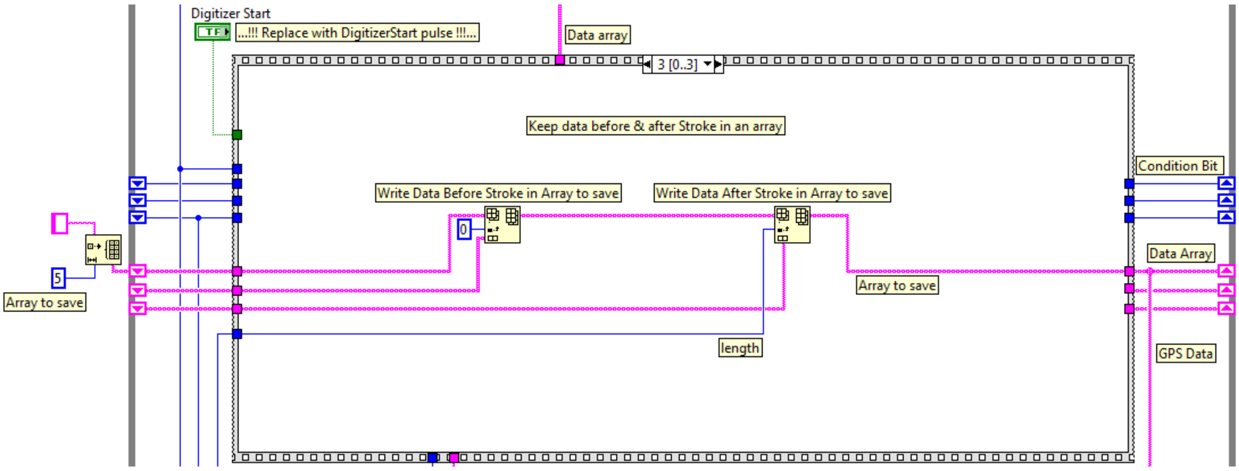


Figure 32 - Remplissage du tableau à sauvegarder

6.6 Ecriture du fichier txt

Dans la première case de la séquence d'écriture on récupère le 'time stamp' qui sera utilisé comme entête pour le fichier d'acquisition et on définit à quel emplacement du disque dur le fichier devra être créé (base path).

Dans la seconde case, comme le 'Array to save' ne se remet jamais à zéro durant l'exécution du programme on doit sélectionner uniquement les données correspondantes à la dernière impulsion du 'time stamp' pour l'enregistrement dans le fichier txt.

Et dans la troisième case, on ferme le fichier txt et on finalise la procédure d'acquisition des données GPS.

A noter qu'en cas de panne de l'entête GPS, la fenêtre 'disable' contient un programme qui génère une entête de fichier .txt avec l'heure et la date de l'ordinateur au lieu des données du GPS. Et concernant les blocs 'Get GPS Data' et 'GPS String Split' ils n'ont pas été programmés dans le cadre de ce travail, ils ont simplement été récupéré du code de M. Carlos Romero traitant de l'acquisition des données de courant au Säntis.

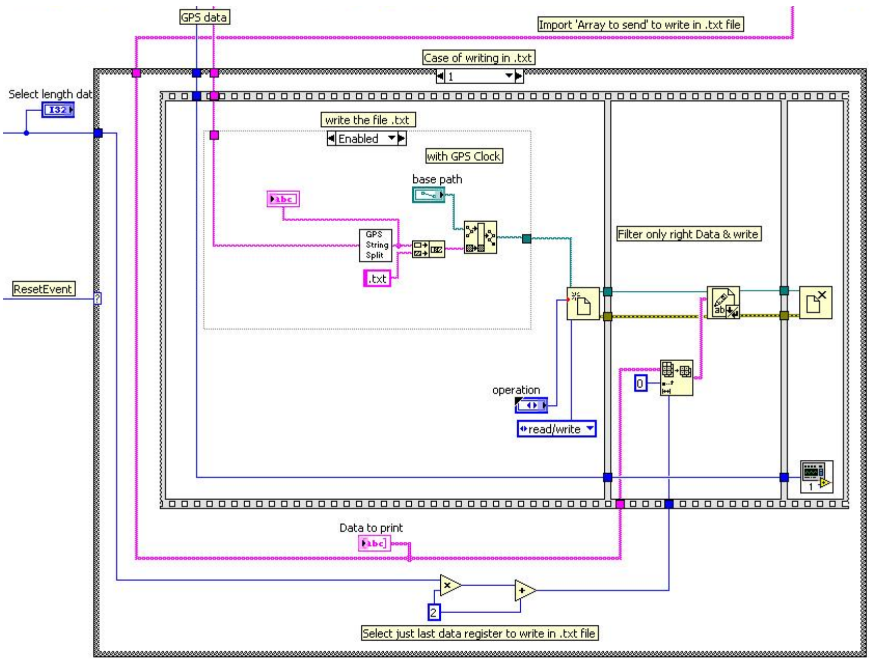


Figure 33 - Ecriture du fichier txt

6.7 Description du front panel

Le front panel du programme d''acquisition des données de l'EFM-100 est fractionné en deux parties à l'image des figures 34 et 35.

La partie 1 comprend les informations relatives à l'acquisition des données du moulin. Affichage graphique, affichage du champ électrostatique instantané, enclenchement des alarmes, emplacement du dossier de sauvegarde des données, affichage du dernier time stamp et le poussoir simulant l'impulsion générée lors d'un évènement pour lancer la procédure de sauvegarde des données.

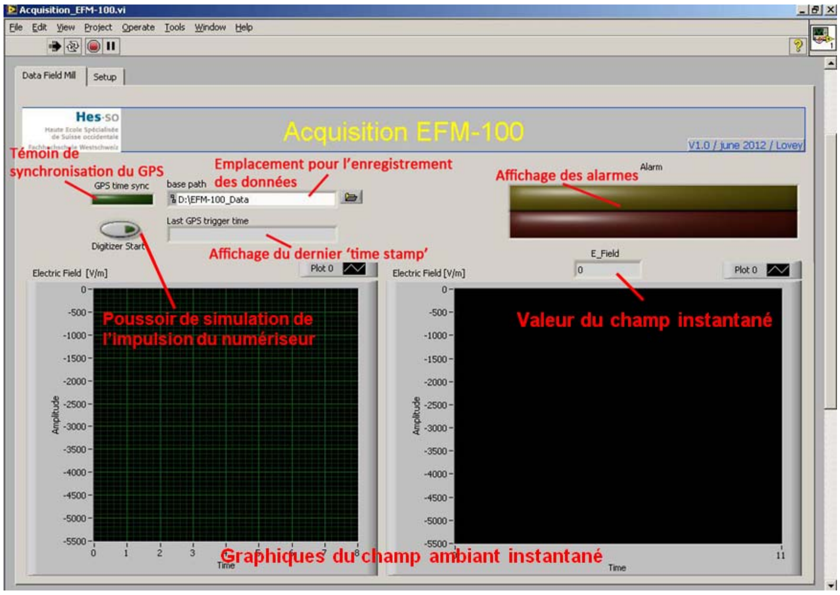


Figure 34 - Front panel du programme d'acquisition

La partie 2 renferme les paramètres variables de divers aspects de la routine d'acquisition qui permettent d'adapter la configuration du programme. Ces variables sont séparées en trois blocs se rapportant au réglage du port sériel, de l'écriture du fichier txt et du programme en général. Elle dispose également d'un poussoir 'STOP' pour interrompre l'exécution du programme.

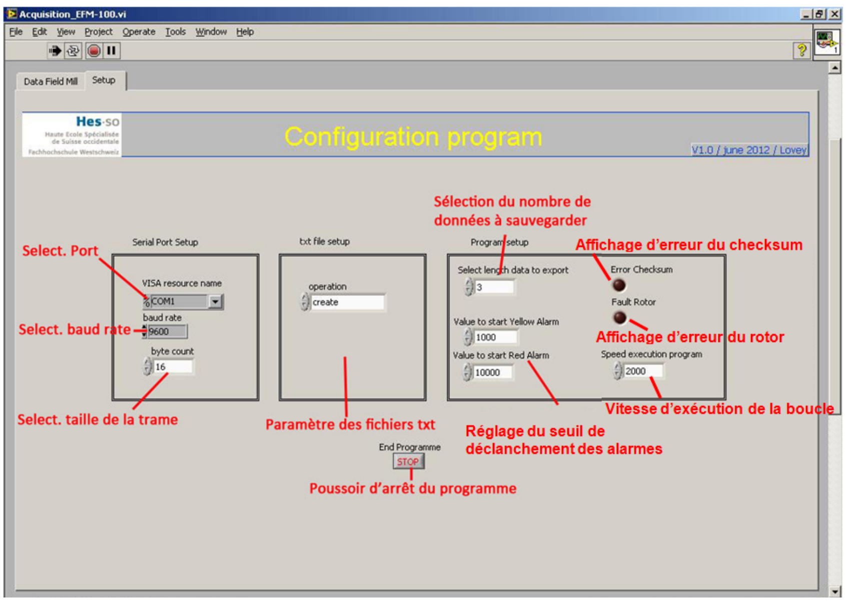


Figure 35 - Front panel config

7. Tests

7.1 Test avec Termite

La routine d'acquisition a été testée pas à pas durant son développement au moyen du logiciel de communication sur port sériel 'Termite 2.9'. En envoyant des trames fictives, il a été constaté que la routine d'acquisition LabVIEW est fonctionnelle et que les données sont enregistrées sur fichier .txt conformément au schéma de la figure 19.

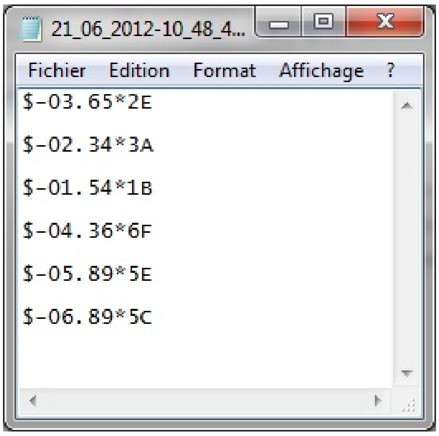


Figure 36 - Exemple de fichier de sauvegarde de données

8. Conclusion

8.1 Bilan projet

A mes yeux, l'intérêt principal de ce projet a été d'une part qu'au départ il n'y avait absolument rien, en dehors de l'installation de mesure de courant et de champ électromagnétique existante sur laquelle notre système de gestion de données va se greffer, concernant le choix du matériel, la conception de l'installation, l'appréciation des simulations, des mesures, le traitement et la sauvegarde des données du moulin à champ électrostatique tout était à bâtir de toutes pièces. Et d'autre part qu'il m'a été possible de mieux cerner certains phénomènes de la physique dans le domaine de la foudre, notamment le champ électrique ainsi que de découvrir de nouveaux outils propre à la recherche tel que COMSOL Multiphysics ou relatifs à la programmation comme LabVIEW.

Durant l'avancement de la procédure d'évaluation du champ électrique à mesurer sur le site du Säntis, j'ai pu prendre conscience qu'il n'est pas forcément évident d'interpréter les résultats d'une simulation. On obtient des valeurs qui nous paraissent énorme, certes, mais il n'est pas aisé d'évaluer leur exactitude. L'étude de sensibilité du modèle m'a permis de découvrir une méthode très simple pour tirer le meilleur profit possible d'une simulation.

Le développement de la routine d'acquisition des données du moulin est un point que j'estime très intéressant dans ce projet car au travers de cette partie il m'a été donné l'occasion de travailler avec LabVIEW. Et dans un futur professionnel relativement proche, il est probable que je sois amené à travailler avec ce programme dans des applications diverses et variées.

Le seul regret que je déplore dans ce travail, c'est de ne pas avoir reçu le moulin à champ durant les 8 semaines assignées à la réalisation de ce projet. Cela m'aurait permis de m'immerger plus profondément dans les tâches de tests et de mesures avec le moulin et mon programme ainsi que de finaliser l'installation sur place, au Säntis.

8.2 Poursuite des travaux

Etant donné que le moulin à champ ne nous est pas parvenu avant la fin du délai imparti pour ce travail de diplôme, aucun test d'acquisition des données du moulin n'a pu être exécuté en temps réel avec le programme LabVIEW. Ces tests seront donc la prochaine chose à faire pour finaliser ce projet. Peut-être qu'il sera nécessaire de procéder à quelques adaptations du programme afin que son fonctionnement soit optimal.

Des mesures en laboratoire devront encore être effectuées pour certifier la précision de mesure du moulin et la justesse des résultats. Ces mesures auraient dû être effectuées dans le cadre de ce travail mais malheureusement à cause du gros retard dans la livraison du moulin il n'a pas été possible de déduire cette tâche du cahier des charges.

Une fois les tests terminés, il restera à apporter une modification dans le code afin de rendre le moulin fonctionnel avec l'installation en service au Säntis. Il faudra remplacer le poussoir 'Start Digitizer' du programme LabVIEW par l'impulsion qui va arriver physiquement sur le port RS232 de la carte GPS lors d'un évènement.

Lorsque cette substitution aura été effectuée et testée, l'installation pourra être effectuée au Säntis. L'EFM-100 ainsi que tous les appareils nécessaires à son fonctionnement seront greffés à l'installation existante. Une liste du matériel à disposition pour effectuer cette installation est répertoriée en annexe 7.

Durant une période qui sera déterminée à compter de sa date de mise en service sur le site, les mesures du moulin feront l'objet de tests et de contrôles qui permettront de statuer sur les informations qu'il fournira, sur la situation de son emplacement,… ou autres. Cette période d'essai vise à optimiser son installation pour obtenir des mesures les plus précises possibles.

9. Références

Réf. [1] image Wikipédia

Réf. [2] Datasheet « Mission Instrument » Electric Field Mill Operation

Réf. [3] Datasheet de l'EFM-100

Réf. [4] & [5] Instrumentation of the Säntis Tower in Switzerland for lightning current measurements
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Rubinstein, Marcos; Zweiacker, Pierre; Daout, Bertrand
Publié dans: International Journal of Plasma Environmental Science & Technology,
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Réf. [6] Fichier txt provenant de CGIAR-CSI SRTM digital elevation data (DEM)

Réf. [7] Numerical solution of the leader progression model by means of the finite element method
A. Borghetti1, F. Napolitano1, C.A. Nucci1, M. Paolone1, M. Bernardi2

Réf. [8] Datasheet de l'EFM-100

Réf. [9] Manuel EFM-100

10. Remerciements

Je tiens à remercier toutes les personnes qui m'ont épaulé dans ce travail.
Merci au professeur Davide Pavanello pour m'avoir suivi durant ce projet.

Merci aux scientifiques de l'EPFL et de l'Heig-VD de m'avoir autorisé à réaliser ce travail, notamment, aux professeurs Farhad Rachidi, Marcos Rubinstein et Mario Paolone, ainsi que pour leurs précieux conseils
Merci à M. Carlos Romero pour la visite des installations du Säntis et son soutien continu.
Merci à M. Alexander Smorgonskiy pour l'aide au développement du modèle sur COMSOL.
Merci à M. Aldo Vaccari pour ses conseils sur LabVIEW.

Merci enfin à mes collègues de classe pour l'agréable atmosphère de travail partagée au cours de ce projet.

11. Annexes

Annexe 1 - Datasheets EFM
Annexe 2 - Données météo
Annexe 3 - Rapport du travail sur les simulations au moyen d'éléments finis
Annexe 4 - Simulations graphiques et modèles
Annexe 5 - Simulations sous la coupole
Annexe 6 - Datasheets
Annexe 7 - Matériel à disposition

12. Date et signature

Sion, le 9 juillet 2012 Jérôme Lovey

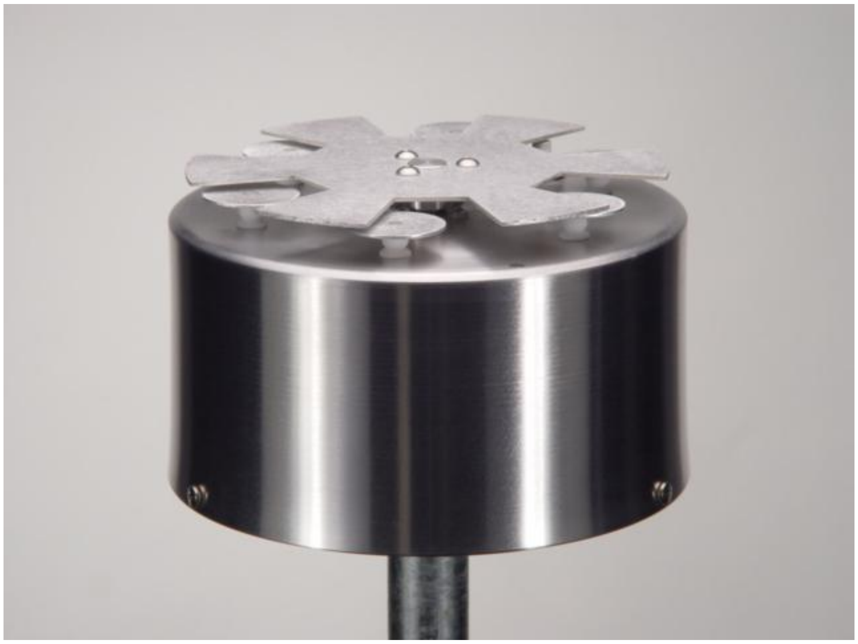
Annexe 1

Datasheets EFM

Jérôme Lovey, TD - 2012

BOLTEK CORPORATION

Lightning Detection



EFM-100 Atmospheric Electric Field Monitor

Installation/Operators Guide

EFM100-1000120-050205

BOLTEK LIGHTNING DETECTION

EFM-100 Atmospheric Electric Field Monitor

Disclaimer

EFM-100 lightning data is only approximate and should not be used for safety applications. Strike and storm locations indicated and alarm statuses may be erroneous and should not be used to safeguard personnel, equipment or data.

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FCC Compliance Statement
For United States Users

This equipment is tested and found to comply with the limits for a Class B digital device, pursuant to Part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio or television reception. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause interference to radio and television reception, which can be determined by turning the equipment on and off, the user is encouraged to try to correct the interference by one or more of the following measures.

- Reorient or relocate the receiving antenna.
- Increase the separation between the equipment and the receiver.
- Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.
- Consult the dealer or an experienced radio/TV technician for help.

WARNING

The connection of a non-shielded equipment interface cable to this equipment will invalidate the FCC Certification of this device and may cause interference levels which exceed the limits established by the FCC for this equipment. It is the responsibility of the user to use a shielded interface cable with this device. If this equipment has more than one interface connector, do not leave cables connected to unused interfaces. Changes or modifications not expressly approved by the manufacturer could void the user's authority to operate the equipment.

For Canadian Users

This Class B digital apparatus meets all requirements of the Canadian Interference-Causing Equipment Regulations.

Cet appareil numérique de la class B respecte toutes les exigences du Règlement sur le materiel brouilleur du Canada.

CAUTIONS

EFM-100 lightning data is only approximate and should not be used for safety applications. Strike and storm locations indicated and alarm statuses may be erroneous and should not be used to safeguard personnel, equipment or data.

Install the EFM-100 Field Mill on a calm clear day when no thunderstorms are expected.

If you are not experienced in safe antenna installation using appropriate safety equipment you should refer installation to an experienced antenna installer. (See Television Antennas in the Yellow Pages)

LIGHTNING HAZARD

EPM-1 connections are not optically isolated from the roof mounted field mill. Dangerous voltages may occur should lightning strike at or near the field mill.

IMPORTANT

The EFM-100 field mill needs to be grounded for proper operation and for lightning and electrical safety. Connect the field mill green ground wire and the field mill mounting hardware to your building central ground through a suitable sized grounding wire according to your local electrical code.

Table of Contents

Table of Figures

Chapter
1

Introduction

Congratulations on your purchase of a Boltek EFM-100 Electric Atmospheric Electric Field Monitor. The EFM-100 is a low cost, high quality atmospheric electric field monitor which uses your personal computer to display and record data. The EFM-100 not only detects nearby lightning but can also detect the high electric field conditions which preceded lightning.

EFM-100 lightning data is only approximate and should not be used for safety applications. Strike and storm locations indicated and alarm statuses may be erroneous and should not be used to safeguard personnel, equipment or data.

Up to four field mills can be monitored using the included software. Field mills can be directly connected to the display computer (USB or COM port) or connected to a remote computer with data transmitted over a network.

Your EFM-100 package should contain:

- 1 EFM-100 field mill,
- 1 fiber optic cable,
    - Standard length 100 feet (30 meters),
    - Optionally 150 feet (45 meters) or 200 feet (60 meters),
- 1 UTP power cable,
    - Standard length 100 feet (30 meters),
    - Optionally 150 feet (45 meters) or 200 feet (60 meters),
- 1 EFA-10 fiber optic adapter,
- 1 EPM-1 power module,
- 1 AC wall adapter power supply,
    - 120VAC to 12VDC for North America,
    - 220VAC to 12VDC for Europe,
- 1 DB-9 male to DB-9 female RS232 cable,

1 field mill grounding wire
5 sensitivity plugs (0.75X, 0.5X, 0.33X, 0.25X, 0.2X),
1 mast (¾" NPT X 6")
1 mounting flange
1 CDROM containing Windows software and USB drivers,
1 user manual (this is it)

Unpack your EFM-100 and make sure all the parts are included.

Theory of Operation

Electric fields develop wherever there is a difference in electric potential. If the electric field gets high enough you can feel your hair stand on end (if this happens outdoors during a thunderstorm crouch down with your feet together as you are about to be struck by lightning.) An electric field is what attracts your hair to a charged comb or a charged balloon.

Electric field is measured in Volts per meter (1 meter = 3.28 feet.) The electric fields which accompany thunderstorms normally measure in the thousands of Volts per meter, usually abbreviated to kV/m. Lightning can be detected as a sudden change in the electric field.

The electric charge contained in a thundercloud also generates an electric field. This field can be measured on the ground

For an accurate electric field reading the field mill needs to be mounted flush with the ground. Mounting the field mill flush with the ground is not practical however as water, dirt, insects, etc will collect around the sense electrodes and contaminate the electrode insulators.

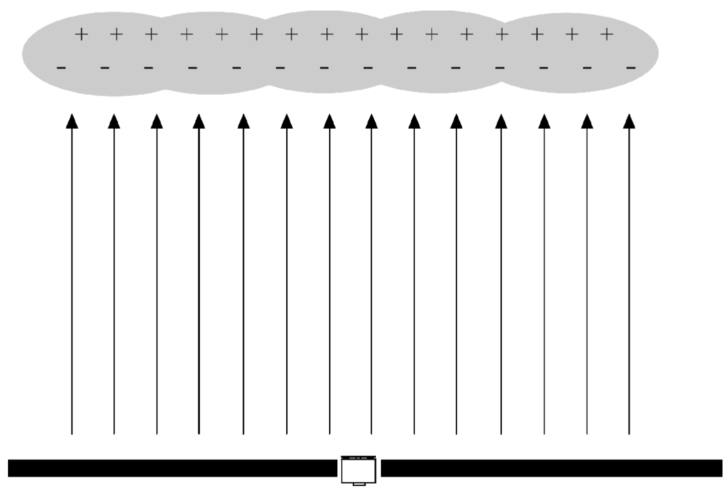


Figure 1: Electric Field Mill at Ground Level

Mounting the electric field mill above the ground surface will enhance the electric field resulting than an incorrect high reading. Sensitivity Plugs are provided to reduce the sensitivity of your field mill and compensate for the higher field mill readings.

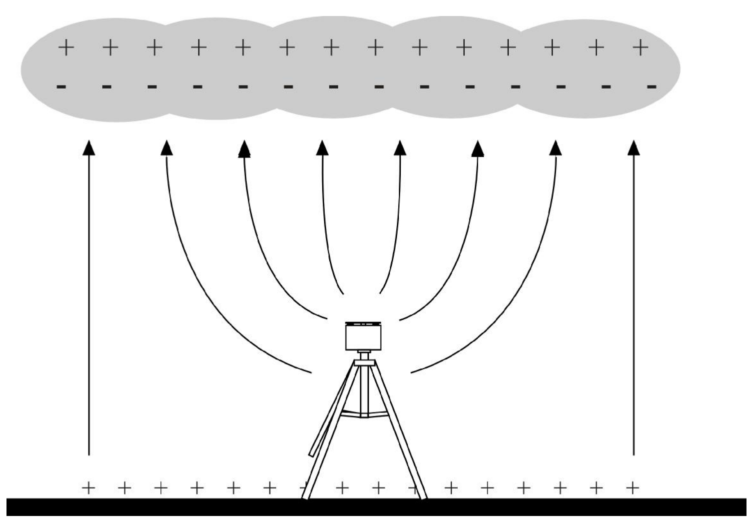


Figure 2: Intensification of Electric Field

The EFM-100's electric field mill senses electric field by repeated exposing and shielding a series of sense electrodes.

An electric field mill uses a mechanical chopper to alternately shield and expose several sense plates to an electric field. When the sense plates are exposed to the electric field an electric charge is drawn from ground to the plates through a sense resistor. When the sense plates are shielded from the field the charge flows back to ground, again through the sense resistor. This moving charge is an electric current which is measured as an AC voltage across the sense resistor. The size of the voltage is proportional to the size of the electric field applied to the plates.

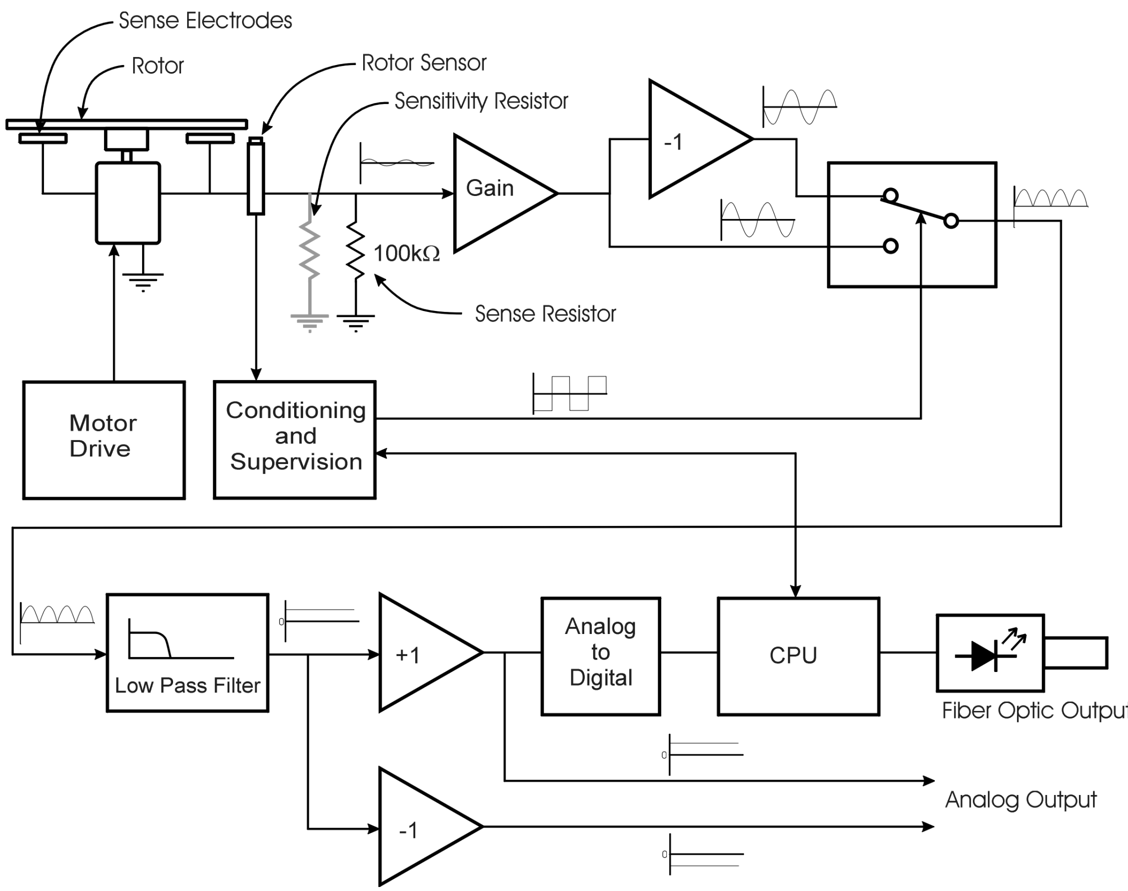


Figure 3: Field Mill Block Diagram

Charge flowing onto and off of the sense electrodes will develop a voltage across the sense resistor. This voltage is amplified and fed into an analog switch along with an out of phase version of the signal.

Chapter 2

Installation

Connect and test your EFM-100 on the ground before permanently mounting the sensor unit. Install the software on your computer and connect the field mill as shown below. The field mill should respond to charged objects brought near it. Most plastic objects can be easily charged by rubbing them on your clothes.

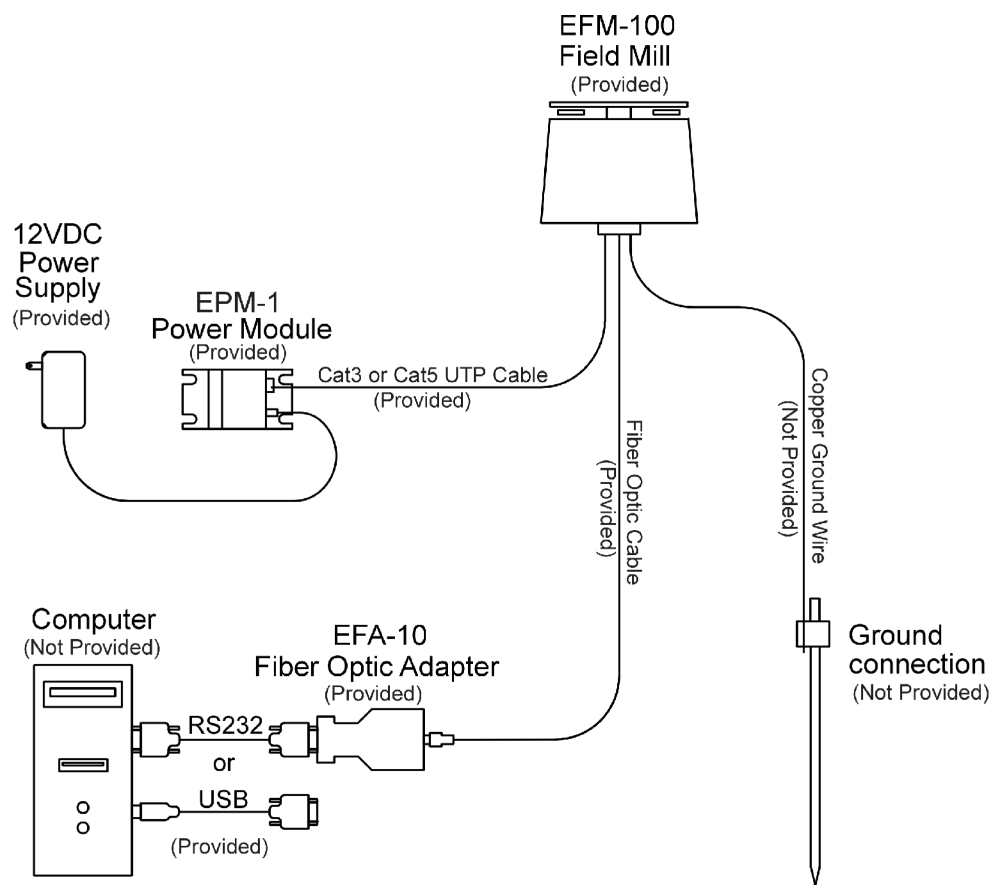


Figure 4: EFM-100 Connection Diagram

EFM-100 Display Software Installation

Insert the provided EFM-100 Software CD into your CD-ROM drive. The setup program should start automatically. If the setup program does not start automatically you can start it manually by clicking on **Start…Run…,** type **d:setup.exe** then click OK.

Once the software is installed you can run the EFM-100 display software by clicking on **Start…All Programs...Boltek…EFM-100 Electric Field Monitor**.

Instructions for installing USB Serial Adapter Driver Software

1) Plug the USB adapter cable into the computer's USB port.
2) The "Welcome to the Found New Hardware Wizard" should appear. If it doesn't go to step 8.
3) Ensure that the provided USB driver CD has been inserted into your CD-ROM drive.
4) Select the option: "Install the software automatically (Recommended)."
5) Press "Next"
6) Windows should find the "Prolific USB-to-Serial Com Port" driver.
7) Press "Finish" when prompted by Windows to complete the installation.

If the "Found New Hardware Wizard" did not appear in step 2

Open Device Manager by doing the following:
a) Click on "Start" and then "Control Panel."
b) Switch to Classic View (if in Category View).
c) Double click on "System."
d) Select the Hardware tab.
e) Press the "Device Manager" button.
Under "Port (COM & LPT)," look for a USB Device entry with a yellow exclamation point by it.
Right click on the USB Device and select "Update Driver"
This should bring up the "Welcome to the Hardware Update Wizard."
Ensure the product driver CD (provided) is inserted in your CD-ROM drive.
Select the option: "Install the software automatically (Recommended)."
Press "Next." Now begin at step 5 above and continue.

Hardware Installation

The EFM-100 field mill mounts on a ¾" NPT (National Pipe Thread) threaded pipe (Note that ¾" NPT pipe measures 1" outside diameter)

A short length of ¾" NPT threaded pipe and a ¾" NPT mounting flange are provided for mounting the field mill on a horizontal surface. Longer lengths of threaded pipe are available at your local hardware store. Antenna mounting tripods are available at your local

Radio Shack store or your local television antenna installer (see Television Antennas in your Yellow Pages).

Install the EFM-100 Field Mill on a calm clear day when no thunderstorms are expected.

Your local antenna installer can do a safe and professional field mill installation and can also ensure that the field mill is properly grounded.

If you are not experienced in safe antenna installation using appropriate safety equipment you should refer installation to an experienced antenna installer. (See Television Antennas in the Yellow Pages)

Choosing an Outdoor Mounting Location

If possible choose a mounting location for your field mill which will provide easy access for maintenance. While your field mill should run for many years with little or no maintenance, cleaning or de-icing may occasionally become necessary. A location which is easy to access can make this a much easier and safer task.

The choice of a mounting location can affect the operation of the field mill. In general, higher is better.

Mounting the field mill close to tall objects will result low readings as the tall object will shield the field mill sensor.

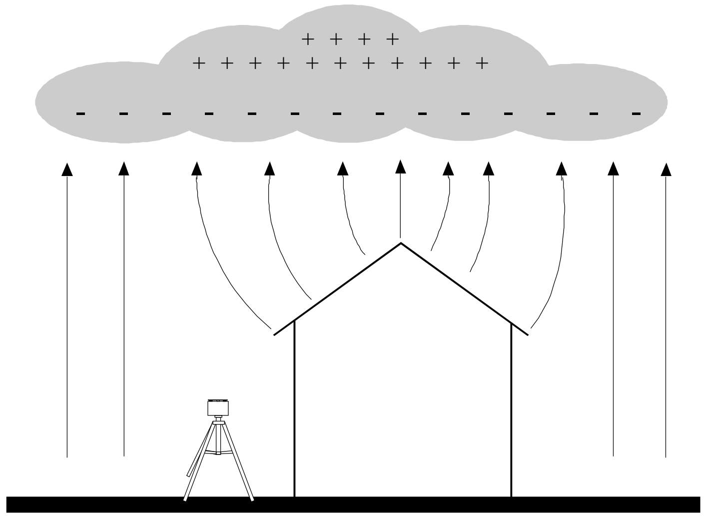


Figure 5: A poor choice of mounting locations

Avoid mounting the field mill in a location where it will be shielded by buildings, tree, or other tall objects. Mount your field mill with similar considerations given to an anemometer.

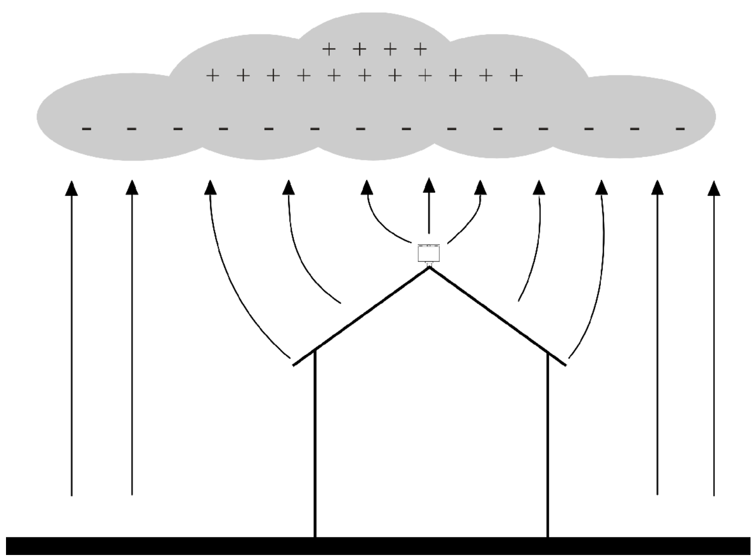


Figure 6: An excellent choice of mounting locations

EPM-1 Power Module

The EPM-1 power module is a connection point for sending DC power up to the field mill and connecting to analog signals from the field mill.

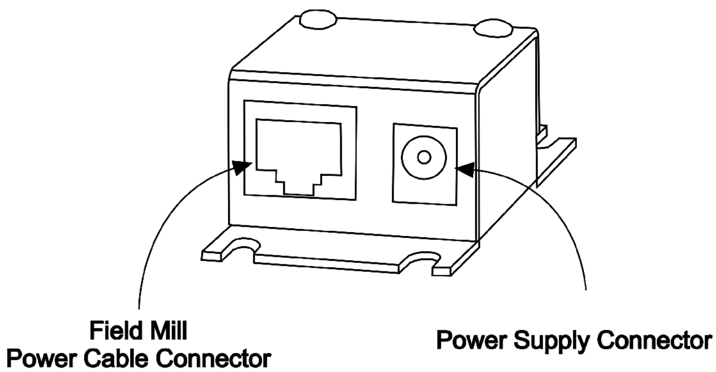


Figure 7: EPM-1 Power Module Connectors

Field Mill Power Cable Connector
Connect the black cable from the EPM-1 Power Module's field mill power connector to the field mill power connector. The cable supplies 12VDC to the field mill and carries the analog output signals back to the EPM-1. See the Lightning Hazard caution in the EPM-1 Analog Output section of this manual.

Power Supply Connector
Connect the provided 12VDC power supply to the EPM-1's power supply connector.

Analog Output

Analog output is available on the EPM-1 Power Module. Output voltage is 1V per kV/m differential, ranging from +20V corresponding to +20kV/m to -20V corresponding to -20kV/m. Note that EPM-1 connections are directly connected to the field mill and a lightning hazard exists at those connections.

> **LIGHTNING HAZARD**
>
> **EPM-1 connections are not optically isolated from the roof mounted field mill. Dangerous voltages may occur should lightning strike at or near the field mill.**

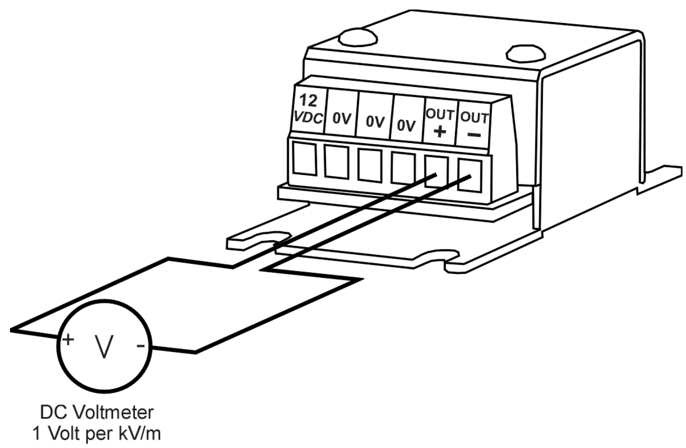


Figure 8: EPM-1 Voltmeter Connections – Differential (Preferred Connection)

If a differential connection is not possible a single-ended connection may be made.

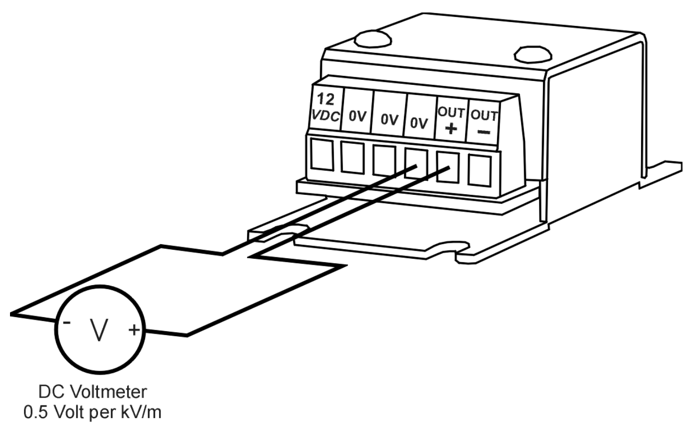


Figure 9: EPM-1 Voltmeter Connections – Single Ended

EFA-10 Fiber Optic Adapter

The EFA-10 Fiber Optic Adapter converts the optical data from the field mill to an electrical signal compatible with your personal computer. Data is transmitted optically from the field mill at 9600 baud, 8 data bits, 1 stop bit, no parity.

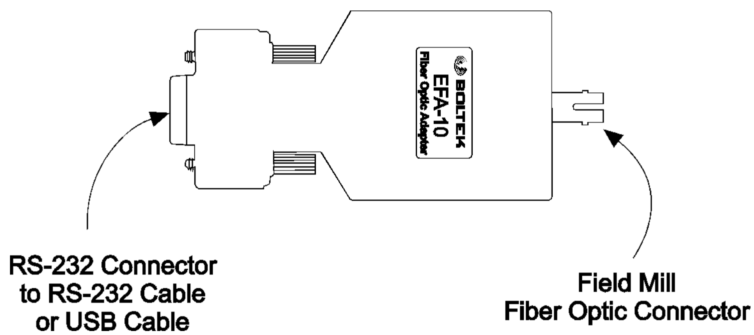


Figure 10: EFA-10 Fiber Optic Adapter

The EFA-10 converts this optical data stream to an electrical signal compatible with your computer's RS232 COM port. A USB adapter cable is provided to convert this RS232 signal to USB if a USB connection is preferred.

ST Fiber Optic Connectors

The EFM-100 transmits its data over a fiber optic cable. The fiber optic cable uses St style connectors on each end.

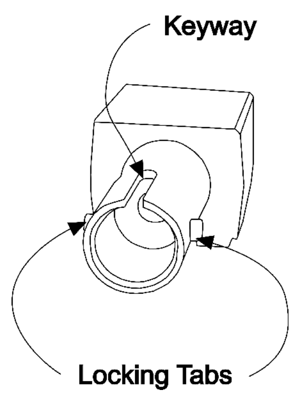


Figure 11: Female Fiber Optic Connector

If the field mill installer is not familiar with ST fiber optic connectors he should familiarize himself with the connectors on the ground, before mounting the field mill on the roof.

Align the key in the male connector with the keyway in the female connector before inserting the male connector into the female connector. Insert the male connector into the female connector and rotate the locking collar until you feel the tabs stop in the detents.

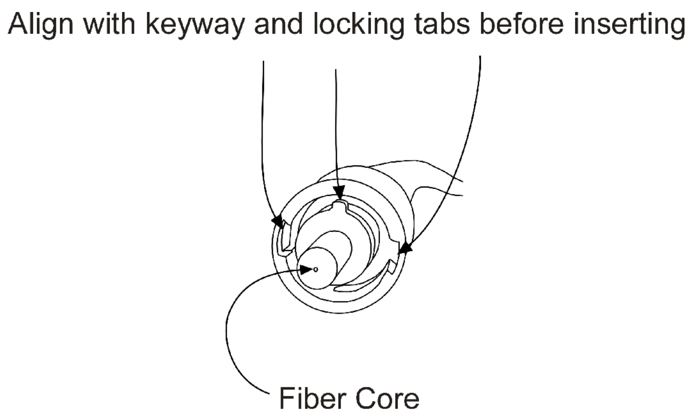


Figure 12: Male Fiber Optic Connector

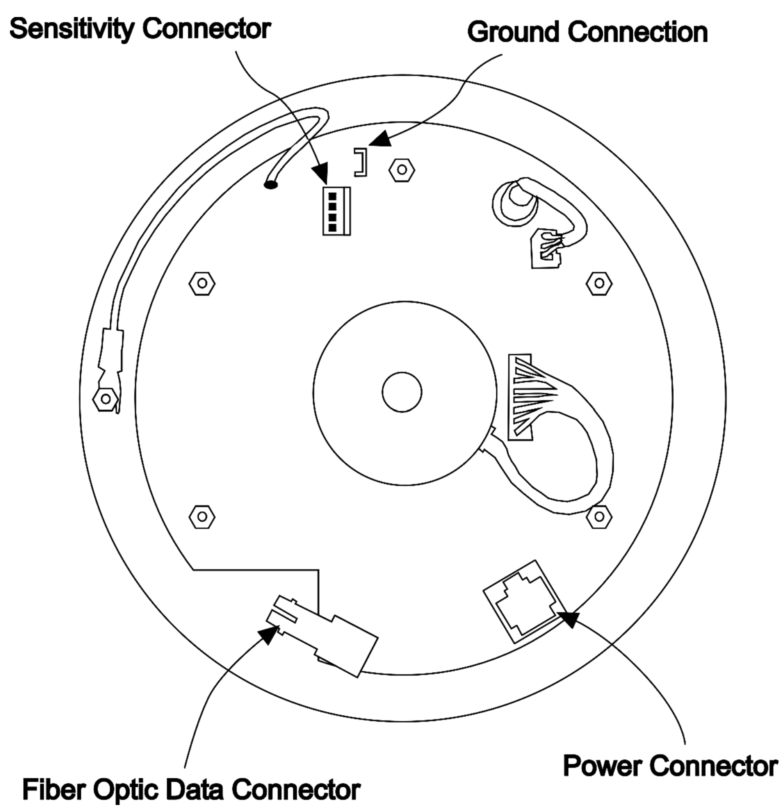


Figure 13: EFM-100 Field Mill Connections

Power Connector
Connect the black cable from the field mill's power connector to the EPM-1 Power Module's field mill power connector. The cable supplies 12VDC to the field mill and carries the analog output signals back to the EPM-1. See the Lightning Hazard caution in the EPM-1 Analog Output section of this manual.

Fiber Optic Connector
Connect the orange fiber optic cable from the field mill's fiber optic connector to the EFA-10's fiber optic connector. The fiber optic cable carries electric field data from the field mill to the EFA-10 and ultimately to your computer. See the detailed drawings of the fiber optic connector and note the keyway and locking tabs on the connectors. Orient the key and locking slots properly on the male connector before attempting to insert the male connector into the female connector.

Ground Connector
Connect the connector end of the green ground wire to the field mill ground connector. The other end of the green ground wire connects to the field mill mount's ground connection. When mounting the field mill it is important to properly ground the field mill and the field mill mount. The field mill is grounded through the green ground wire. The field mill mounting hardware (mast and/or tripod) needs to be grounded though suitable sized copper ground wire to your building central ground point. See **Grounding Detail** for more information.

Sensitivity Connector
The sensitivity connector accepts a sensitivity plug to reduce the sensitivity of the field mill. Several different values are provided so you can choose an appropriate value for your installation. See **Chapter 1: Intensification of Electric Field** for a description of why this is necessary.

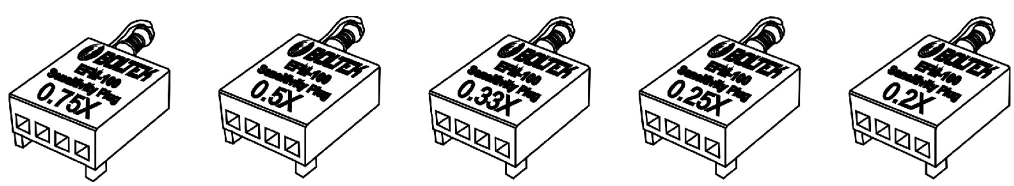


Figure 14: Sensitivity Plugs

With no plug installed the field mill has a relative sensitivity of 1.0
Sensitivity plugs reduce the sensitivity to compensate for the enhanced electric field of a field mill mounted above the surface of the ground. Lower numbers represent lower sensitivities. For example, the 0.25X plug will reduce the sensitivity to ¼ of the field mills normal sensitivity.

Fortunately most installations won't require a precisely calculated correction factor. On a clear day simply choose the sensitivity jumper which produces field values closest to the normal fair-weather electric field of 0.1 kV/m. If electric field readings during thunderstorms routinely exceed 20 kV/m (the limit of the field mill) you should change to a lower value Sensitivity Plug (after the storm and when it is safe to do so.)

Calculating a Precise Sensitivity Value

If you require a precisely calibrated field mill for scientific or other precision applications you will need to calculate a precise correction factor, then order or assemble a custom Sensitivity Plug.

The most accurate method for calculating an exact geometric correction factor is to temporarily run two field mills simultaneously, a temporary reference field mill and the permanent field mill. The temporary reference field mill is mounted flush with the surface of the ground to prevent the electric field enhancement which occurs when objects are mounted above the ground. The permanent field mill is mounted in its permanent location. The correction factor needed is equal to the reference field mill reading divided by the permanent field mill reading.

If two field mills are not available an approximate correction factor can be determined by moving a single field mill from one location to another during a period of stable electric field.

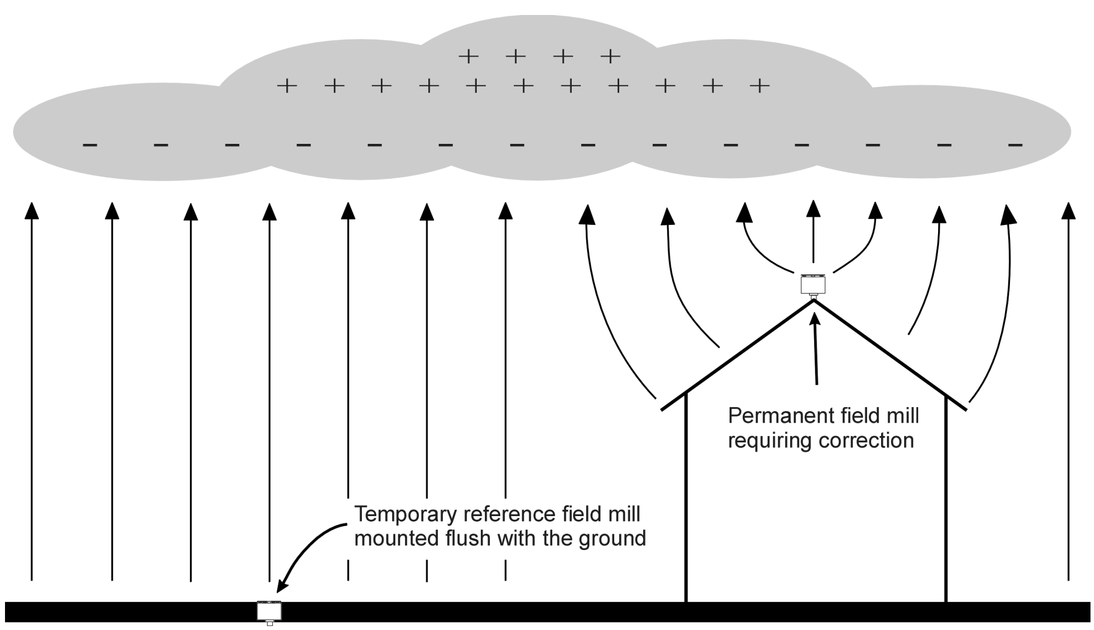


Figure 15: Correcting a Field Mill using a Reference Field Mill

$$correction = \frac{reference}{permanent}$$

Once you have calculated the required sensitivity reduction (correction factor) you can calculate the resistor value needed for the Sensitivity Plug.

$$resistor = \frac{100\ k\Omega}{correction} - 100\ k\Omega$$

For most installations it is not necessary to correct using a reference field mill. It is usually sufficient to choose a sensitivity plug which produces a fair-weather electric field of approximately 0.1 kV/m and does not saturate (above -20 kV/m or +20kV/m) during most thunderstorms. Electric field trends and sudden changes (lightning) are of much more interest than an exact absolute value. Alarm setpoints can be lowered to increase alarm sensitivity or increased to reduce the frequency of nuisance alarms.

Grounding Detail

The EFM-100 field mill needs to be grounded for proper operation and for lightning and electrical safety. Connect the connector end of the green ground wire to the field mill ground connector. Connect the other end of the green ground wire and the field mill mounting hardware to your building's central ground through a #6 bare ground wire or other suitable wire according to your local electrical code. Grounding wire and clamps are available at your local hardware store or electric supplier.

IMPORTANT

The EFM-100 field mill needs to be grounded for proper operation and for lightning and electrical safety. Connect the field mill green ground wire and the field mill mounting hardware to your building central ground through a suitable sized grounding wire according to your local electrical code.

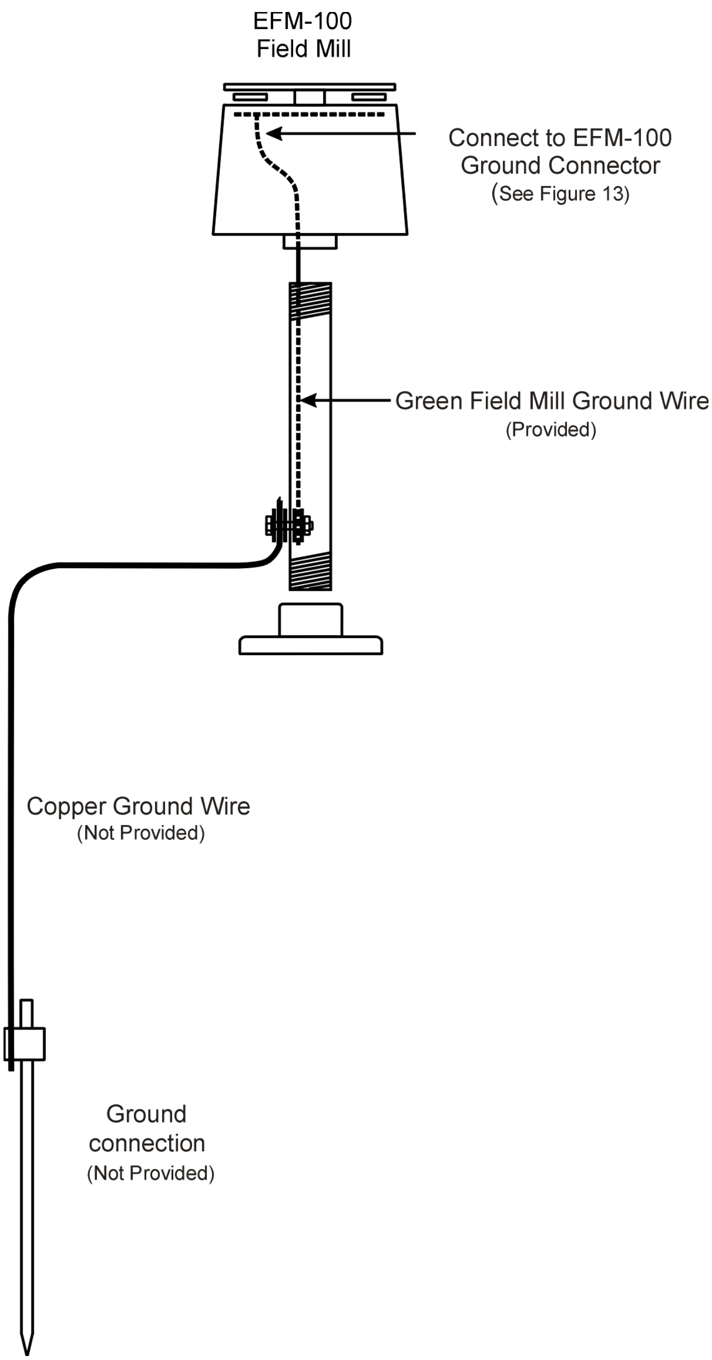


Figure 16: Field Mill Grounding Detail

Chapter 3

Configuring the Software

EFM Options: General

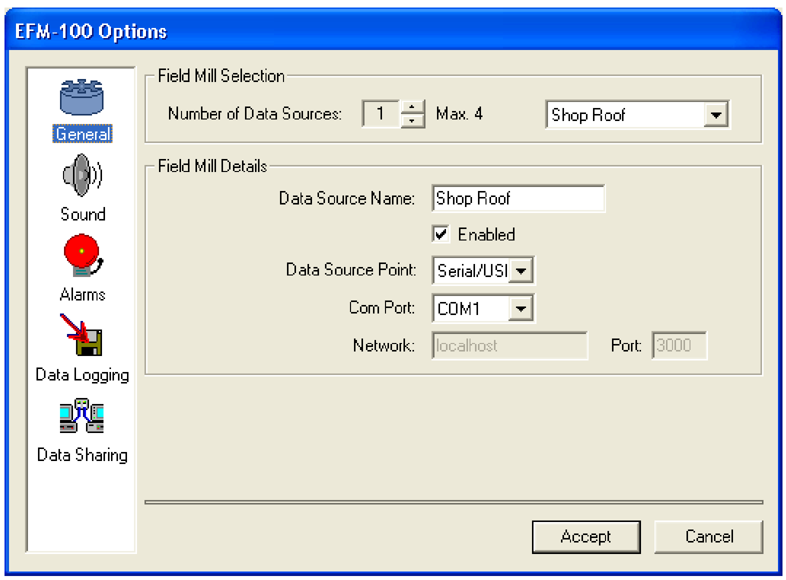


Figure 17: EFM Options - General

Number of Data Sources
Enter the number of field mills for which you would like to display data. The minimum number is 1 field mill. The maximum number is four field mills. If you have more than four field mills you will require a second computer for each additional four field mills creating a multi-monitor display.

Data Source Name
Enter a descriptive name for each field mill. If you are displaying the data from more than one field mill the name will be used to identify the source of the data. Select individual field mills in the Field Mill Selection box above.

Enabled Checkbox
Check this checkbox to enable the display of data for the currently selected field mill.

Data Source Point
Select the type of connection to the field mill: Serial/USB or Network. Select Serial/USB for field mills connected to the computer directly. Select Network to display the data from a remote computer.

Com Port
For field mills connected directly to the computer select the COM port allocated to the connection. For field mills connected using a RS232 COM port this is usually COM1 or COM2. For USB connected field mills this is usually COM3 – COM9.

Network
For remote field mills enter the host and domain name or the IP address of the computer which is sharing a field mill.

Port
For remote field mills enter the port number of the field mill from the computer which is sharing the field mill. See EFM Options: Data Sharing for more information.

EFM Options: Sound

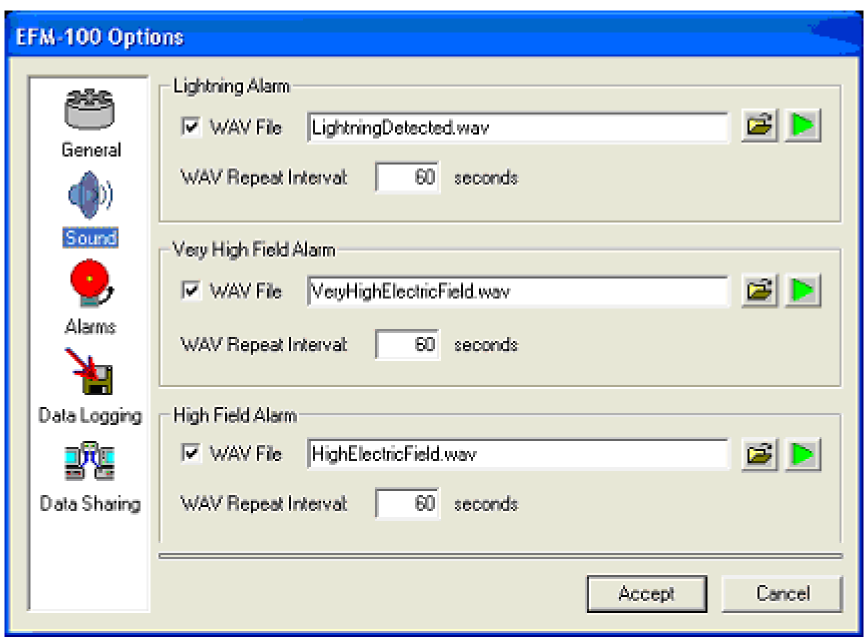


Figure 18: EFM Options - Sound

Configure the sound to play out the computer speakers whenever an alarm activates. You may select a different WAV file for each of the three alarms: Lightning Alarm, Very High Field Alarm, and High Field Alarm.

WAV File Checkbox
Check the checkbox to enable the playing of WAV file sound when the corresponding alarm activates. Clear the checkbox to disable the playing of the WAV sound.

WAV Filename
The WAV Filename is the file which will play out the computer speakers when an alarm is activated. Click on the Browse icon  to select the WAV file from a list.

WAV Repeat Interval
Enter the number of seconds between repeats of the WAV sound.

EFM Options: Alarms

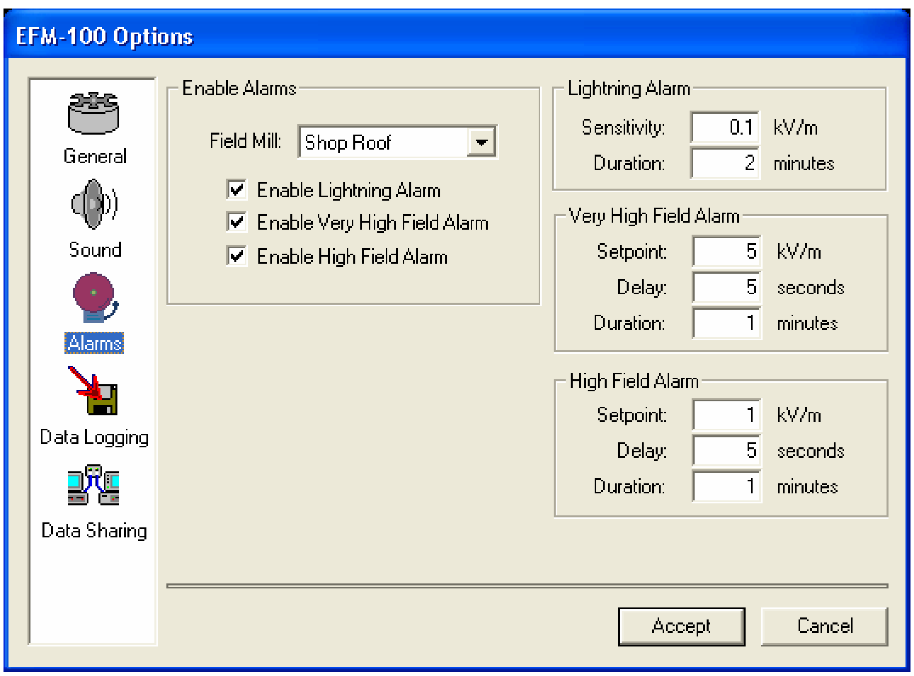


Figure 19: EFM Options - Alarms

Field Mill Selector
Select the field mill for which you would like to enable or disable alarms.

Enable Lightning Alarm Checkbox
Check this checkbox to enable the Lightning Alarm for the currently selected field mill.

Enable Very High Field Alarm Checkbox
Check this checkbox to enable the Very High Field Alarm for the currently selected field mill.

Enable High Field Alarm Checkbox
Check this checkbox to enable the High Field Alarm for the currently selected field mill.

Lightning Alarm Sensitivity
Lightning is detected by the software as a step change in electric field value. Electric field normally changes slowly as clouds slowly pass overhead. Electric charge is redistributed during a lightning strike causing an almost instantaneous change in electric field. Lightning Alarm Sensitivity is the size of the step change that is required to activate the lightning alarm. Lower values make the lightning alarm more sensitive and extend the range. Higher values reduce the sensitivity and reduce the detection range. The minimum recommended value for the Lightning Alarm Sensitivity is 0.1 kV/m. Increasing the value to 0.2 or 0.5 is recommended if precipitation is causing nuisance alarms.

Lightning Alarm Duration
Lightning Alarm Duration is the length of time the lightning alarm will remain active after a lightning event is detected. For the Lightning Alarm to clear there must be no lightning events detected for the period of the lightning alarm duration.

Very High Field Alarm Setpoint
Very High Field Alarm Setpoint is the magnitude of electric field required to trigger a Very High Field Alarm. For example, with a setpoint of 5 kV/m the alarm will activate if the field goes above 5 kV/m or below -5 kV/m.

Very High Field Alarm Delay
The Very High Field Alarm Delay is the length of time the field magnitude must remain above the setpoint before the alarm is activated. If the electric field magnitude drops below the setpoint before the delay expires the delay timer will be reset. For example, with a delay of 30 seconds and setpoint of 5 kV/m the electric field must remain above 5 kV/m or below -5 kV/m for 30 seconds before the alarm activates.

Very High Field Alarm Duration
Very High Field Alarm Duration is the length of time the Very High Field Alarm will remain active once the field drops below the alarm setpoint.

High Field Alarm Setpoint
High Field Alarm Setpoint is the magnitude of electric field required to trigger a High Field Alarm. For example, with a setpoint of 1 kV/m the alarm will activate if the field goes above 1 kV/m or below -1 kV/m.

High Field Alarm Delay

The High Field Alarm Delay is the length of time the field magnitude must remain above the setpoint before the alarm is activated. If the electric field magnitude drops below the setpoint before the delay expires the delay timer will be reset. For example, with a delay of 30 seconds and setpoint of 1 kV/m the electric field must remain above 1 kV/m or below -1 kV/m for 30 seconds before the alarm activates.

High Field Alarm Duration

High Field Alarm Duration is the length of time the High Field Alarm will remain active once the field drops below the alarm setpoint.

EFM Options: Data Logging

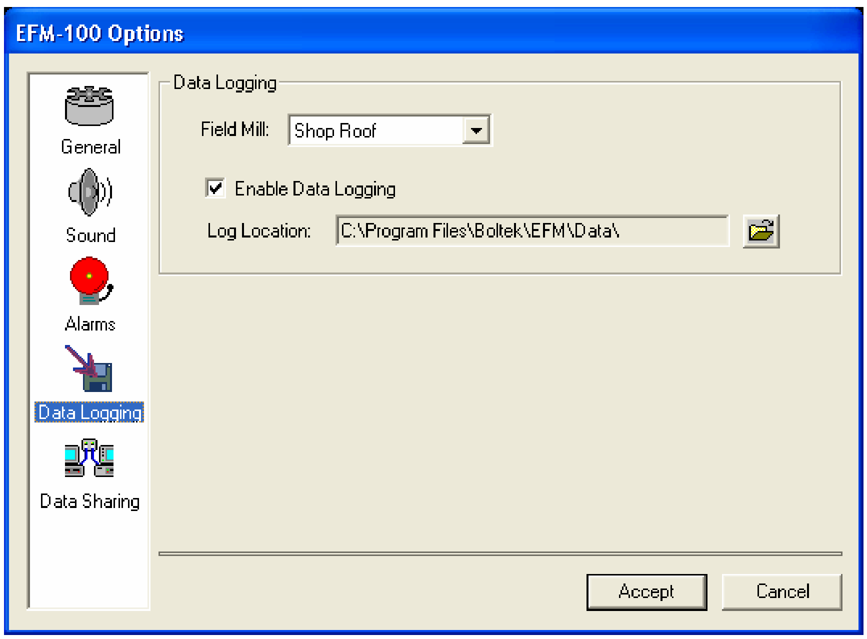


Figure 20: EFM Options – Data Logging

Field Mill Selector

Select the field mill for which you would like to configure data logging.

Enable Data Logging Checkbox

Check the Enable Data Logging checkbox if you would like field mill data to be logged to the hard drive for the field mill selected in the selection box above. Logged data is viewable using the EFMView Electric Field Mill Data Viewer. Select **File…Open…** on the main menu to view the data file. Logging data will consume approximately 1.3 megabytes of hard disk space per field mill per day.

Data files have a filename consisting of the field mill name, the file date, and a efm suffix. For example: “Shop Roof-03252004.efm”. Data files are comma delimited ASCII text files allowing the files to be loaded into spreadsheets or other third party software.

Logfile Location

This is the directory where the data files are stored. Click on the Open icon  to browse for the directory.

EFM Options: Data Sharing

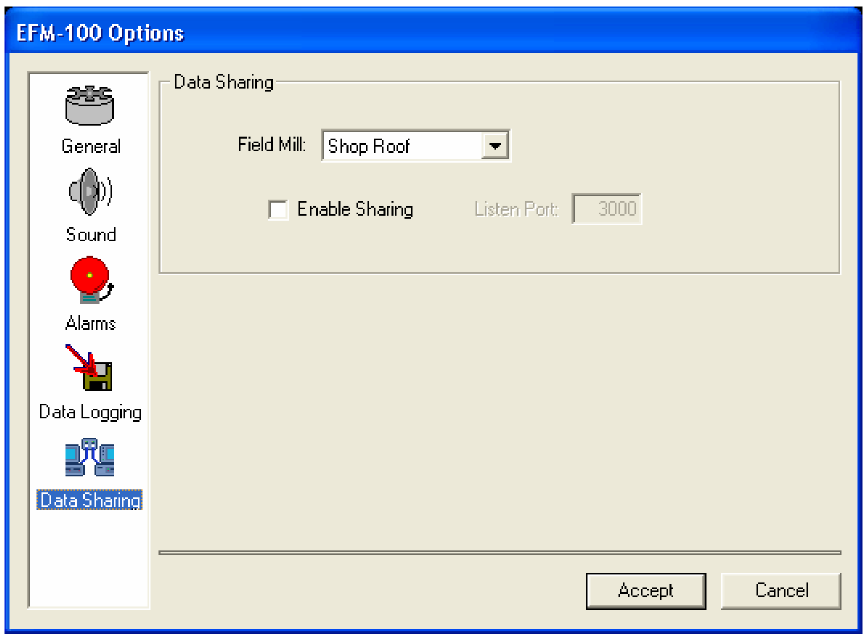


Figure 21: EFM Options – Data Sharing

Field Mill Selector

Select the field mill for which you would like to configure data sharing.

Enable Sharing Checkbox

Check the Enable Sharing checkbox if you wish to share your field mill data with others. If enabled your EFM-100 software will list on the Listen Port for incoming connections. Once a connection has been made the software will begin transmitting field mill data to the remote computer. There is no limit to the number of concurrent connections.

Listen Port

This is the port on which your computer will listen for incoming connections. Each field mill being shared on one computer must have a unique port number.

Chapter 4

Operation

The EFM-100 display software interprets and displays the field mill readings and status. For remote field mills the software also attempts to establish and maintain a network connection with the remote computer's EFM-100 display software in order to receive the remote data. When Data Sharing is enabled the display software will accept remote connections and deliver its field mill data over those connections for others to view.

To start the EFM-100 display software select: Start...All Programs...Boltek…EFM-100 Electric Field Monitor.

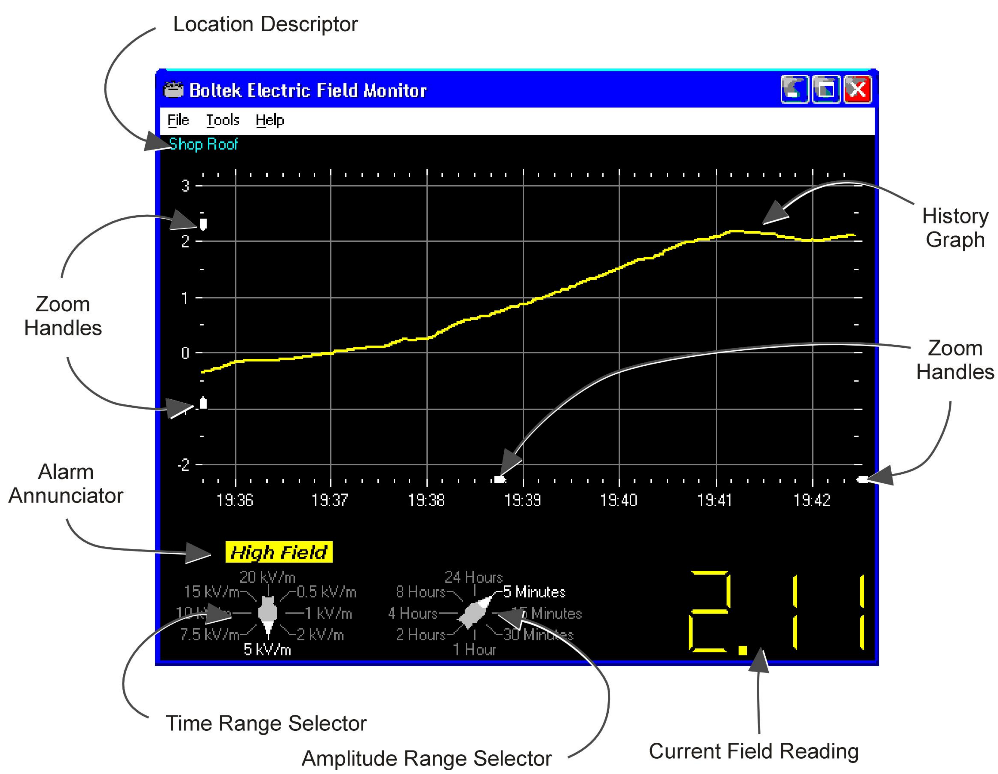


Figure 22: EFM-100 Software Display

Location Descriptor describes the location of the field mill. When the software is configured to display data from multiple field mills the descriptor is important in identifying the source of the data.

The **History Graph** shows the most recent data in graphical form. The history graph is useful in identifying trends in electric field.

Zoom Handles are used for zooming in on an area of interest in the trend graph. There are zoom handles for magnifying the display horizontally (the time axis) or vertically (the amplitude axis.) Click and drag a zoom handle to adjust

The **Current Field Reading** is the amplitude of the electric field at the present time. The current field reading is updated approximately once per second.

The **Time Range Selector** is used to change the scale of the horizontal scale axis.

The **Amplitude Range Selector** is used to change the scale of the vertical amplitude axis.

Interpreting the Data Display

Often the first indication of an approaching thundercloud is a positive field reading followed by a field reversal to a negative field as the cloud moves overhead.

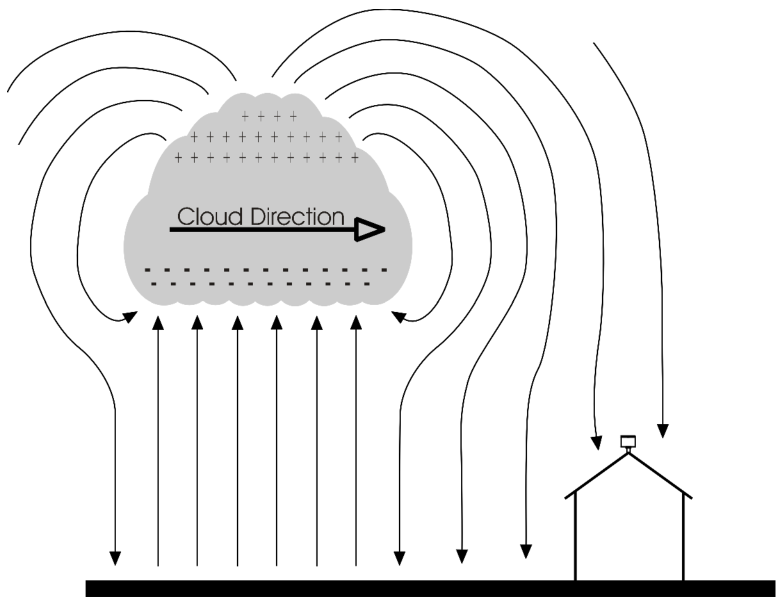


Figure 23: Approaching Thundercloud

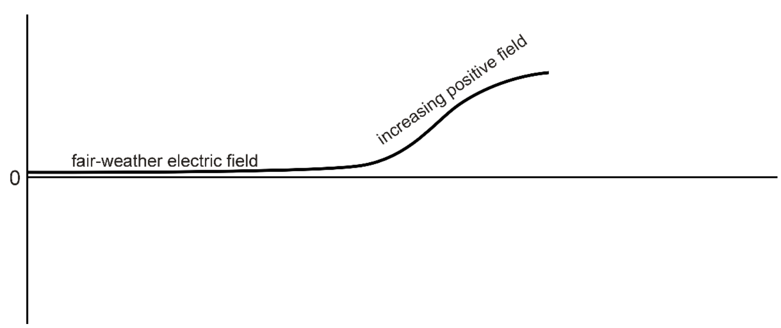


Figure 24: Increasing Field due to Approaching Thundercloud

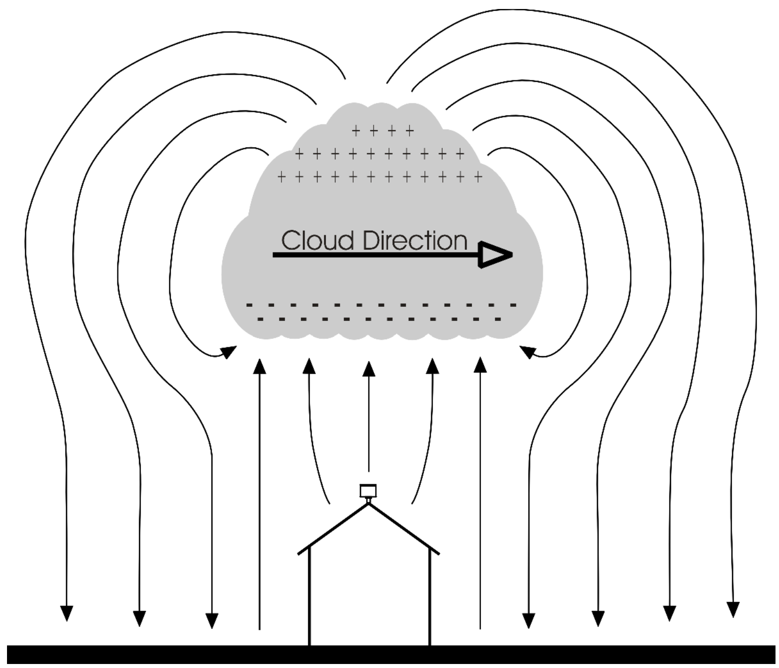


Figure 25: Thundercloud Directly Overhead

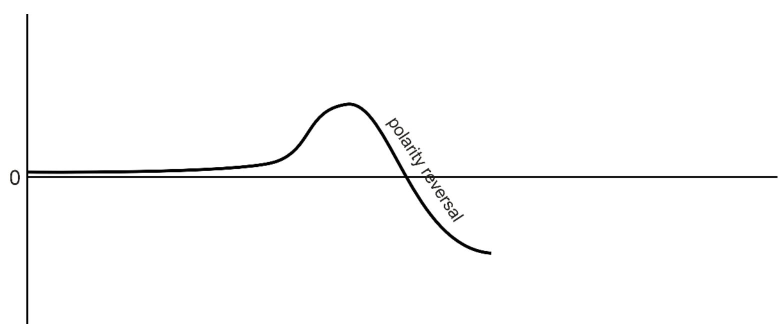


Figure 26: Electric Field Polarity Reversal

With the thundercloud directly overhead the polarity of the field has reversed to a negative electric field.

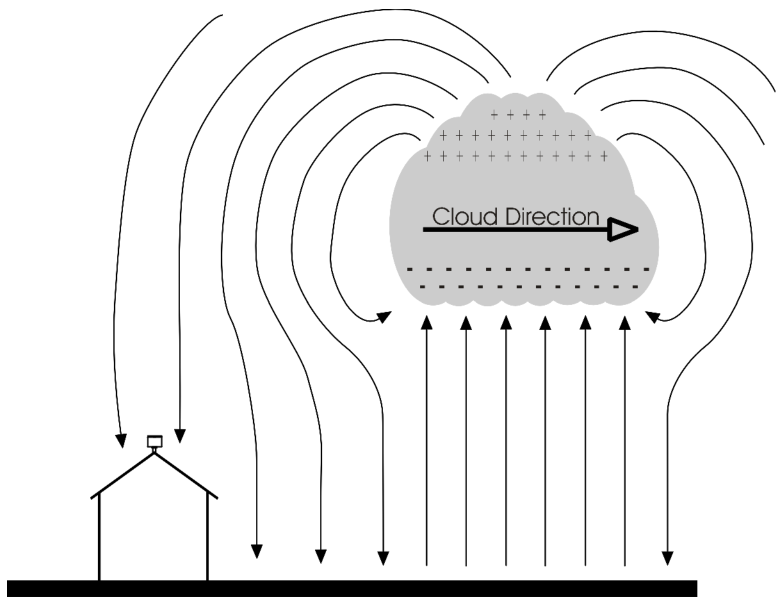


Figure 27: Departing Thundercloud

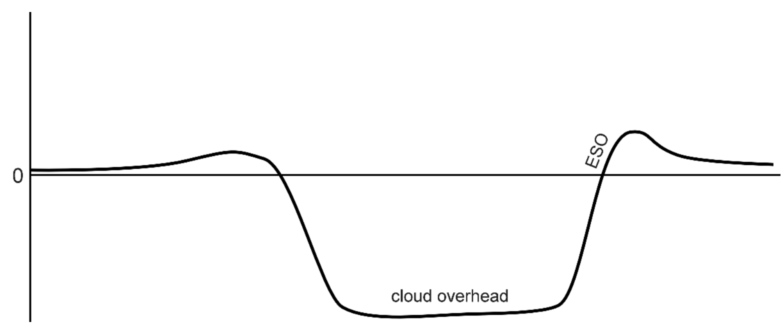


Figure 28: End of Storm Oscillation

Once the cloud has passed over the field will often reverse back to positive before decaying to a normal fair-weather electric field reading of about 0.1 kV/m. This field reversal at the end of the storm has been referred to as the "End of Storm Oscillation" (ESO).

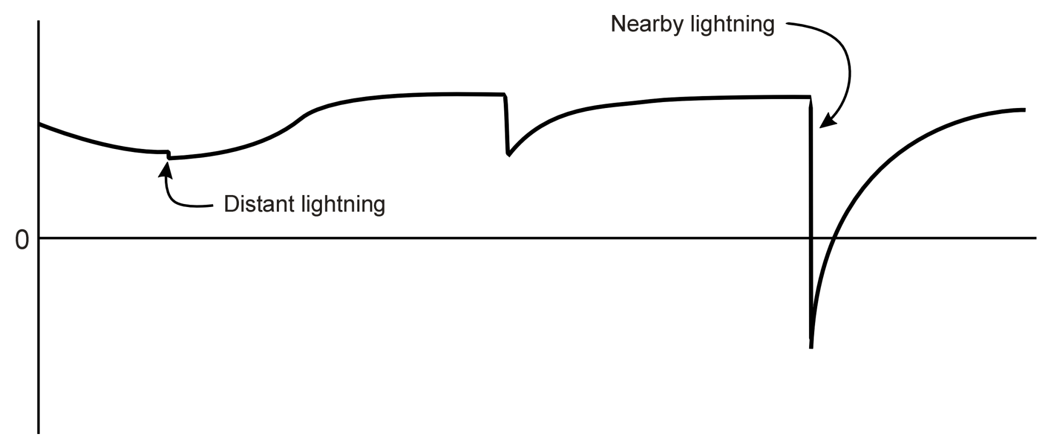


Figure 29: Step Changes in Field Magnitude Indicate Lightning

Step changes in the magnitude of the electric field indicate lightning. Closer lightning produces larger field changes than distant lightning. The EFM-100 can detect lightning out to about 30 miles.

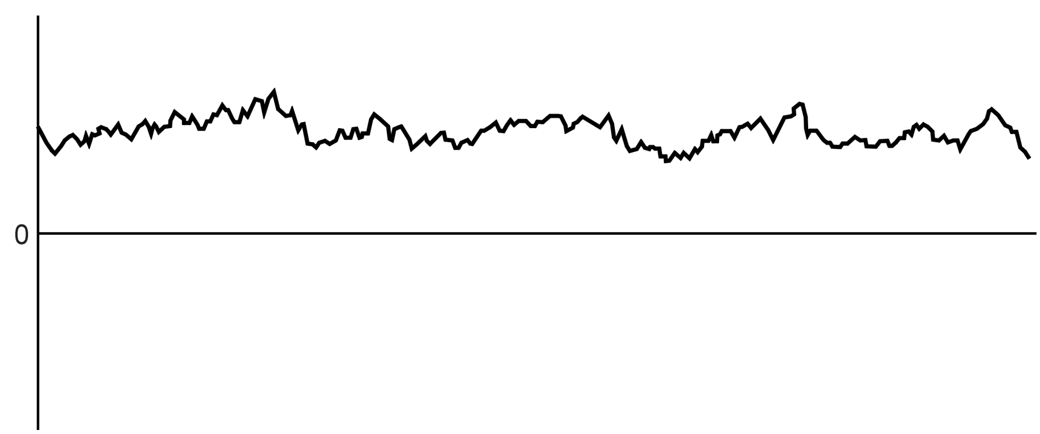


Figure 30: Precipitation Noise

Rain, snow, and dust can carry an electric charge. If charged particles contact the field mill sense plates the electric charge will transfer from the particle to the sense plate and will be detected as noise on the field mill reading. During periods of heavy rain the precipitation noise can get quite severe. Once the storm passes the noise will disappear. Precipitation noise can reduce the ability of the software to detect distant lightning but nearby lightning can still be detected.

Chapter
5

Maintenance

Your EFM-100 should run for years with very little maintenance. An occasional cleaning may be all that is necessary. In most installations even that will not be necessary as rain will wash away any accumulated dirt.

Periodically inspect your field mill to ensure the Teflon insulators are free from dirt or contamination. Watch for spider webs or other debris which could short an electrode to ground (the case.)

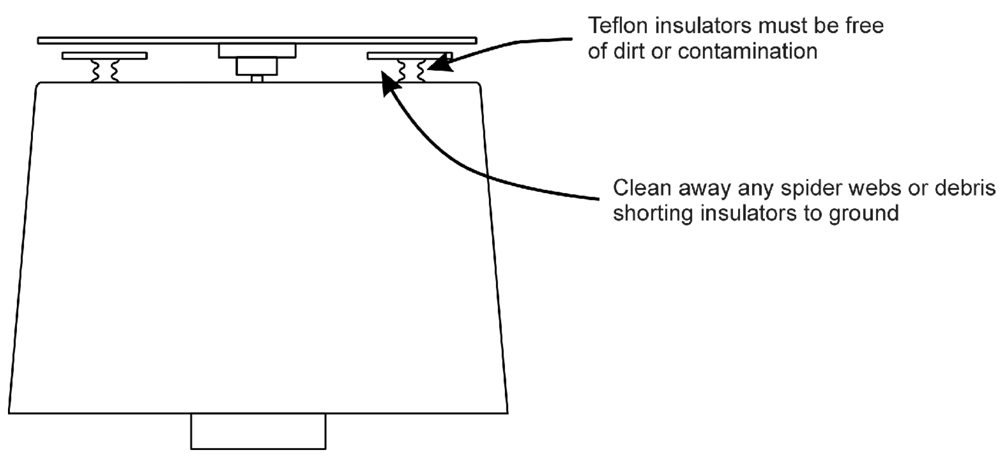


Figure 31: Field Mill Cleaning

Appendix
A

Troubleshooting

Problem:

Signal Lost Fault

Solution:

The EFM-100 software will report a "signal lost" fault if it does not receive data from the field mill for more than a few seconds. You will need to determine why the data is not reaching the software. Possible causes will depend on the type of field mill connection: USB/RS-232 or network.

Remote Field Mill: If the field mill is a remote network connected field mill the problem will need to be solved at the remote computer. Troubleshoot at the remote computer as a USB/RS232 connected field mill.

USB/RS232 Field Mill: If you are experiencing a Signal Lost Fault on field mill directly connected to your computer's USB or RS232 port you will first need to determine if there is data coming from the field mill down the fiber optic cable. Check the power supply to the field mill.

It may be possible to see the optical signal coming down the fiber. At the computer unplug the fiber optic ST connector from the EFA-10 Fiber Optic Adapter. If the field mill is transmitting data the signal should be visible as a faint red dot in the center of the connector's white tip. As the dot is very small (pin prick in size) it may be necessary to dim the room light to see it. If the red dot is visible the field mill is transmitting properly. Check your computer connections and configuration.

It is possible to view the field mill data using HyperTerminal or another terminal program. First exit the EFM-100 display software then start HyperTerminal. Data is transmitted from the field mill at 9600 baud, 8 data bits, no parity, 1 stop bit. RS232 connected field mills usually show up on COM1 or COM2 while USB connected field mills usually show up on COM3, COM4 or even higher com ports.

Problem:

Rotor Fault

Solution:

The EFM-100 field mill continuously monitors the speed of the rotor and ensures it is spinning at the correct speed. If the rotor is found to be spinning either too fast or too slow the supervisory circuitry will change the fault status in the data stream from a 0 (no fault) to a 1 (rotor fault.) The EFM-100 display software will indicate a Rotor Fault.

The field mill rotor may have become obstructed. If the rotor becomes coated with ice during a freezing rain ice storm you can wait for the ice to melt naturally (it wouldn't be safe to try and clear the ice manually when the ground and roof are ice covered.) The field mill will not be damaged by a jammed rotor and will begin to work normally once the ice melts away.

Problem:

Data often appears clipped at 20 kV/m

Solution:

If your data is routinely clipped at +20 kV/m or -20 kV/m your field mill is probably too sensitive. Reduce the field mill sensitivity by changing the Sensitivity Plug to a lower value. See Chapter 2.

Appendix
B

EFM-100 Data Format

The EFM-100 Electric Field Mill transmits data sentences down the fiber optic cable at the rate of ten readings per second. The EFA-10 converts the optical signal to standard RS232 at 9600 baud, 8 data bits, no parity, 1 stop bit.

Electric Field Sentence

$<p><ee.ee>,<f>*<cs><cr><lf>

<p> - polarity of electric field + or -
<ee.ee> - electric field level 00.00 to 20.00
<f> - fault 0: Normal, 1: Rotor Fault
<cs> - checksum in hex 00 to FF
<cr> - carriage return
<lf> - line feed

Example:

+00.33,0*C9 Represents 0.33kV/m with no faults.

Checksum can be ignored for most applications.

Appendix
C

Specifications

EFM-100 Hardware Specifications

Electric Field Range:	-20 kV/m to +20 kV/m
Typical Range of Interest:	-5 kV/m to +5 kV/m
Response Time:	0.1 seconds
Resolution:	Digital Output 0.01 kV/m Analog Output Infinite
Digital Data Cable:	50/125 Multi Mode Fiber Optic Cable with ST Connectors
Digital Data Format:	$<S><EE.EE>*<C><CR><LF> S: sign '+' or '-' C: checksum E: electric field CR: carriage return LF: line feed Example: $-02.34*3A
RS232:	9600 baud, 8 bits, 1 stop bit, no parity
Analog Data Output:	Differential 1V per kV/m Single-Ended 0.5V per kV/m
DC Power Supply:	12-15 VDC, 0.5 Amps
AC Power Supply:	120 VAC, 60Hz (220VAC 50 HZ in Europe)
Motor Type:	Ball Bearing, Brushless DC Motor
Mount:	3/4" NPT Threaded Pipe (Note: 3/4" NPT measures 1" O.D.)
Temperature Range:	-40°F to +140°F (-40°C to +60°C)
Dimensions:	6.7" dia. x 5" (17 cm dia.x 13 cm)
Weight:	2.2 lbs (1 kg)
Shipping Weight:	13 lbs (5.75 kg)

Shipping Dimensions:	18.5" x 13" x 8.8" (47 x 33 x 22 cm)
Warranty:	1 Year

EFM-100 Software Specifications

Operating System:	Microsoft Windows XP, 2000, NT, 98, 95
Alarms:	High Field Alarm, Very High Field Alarm, Lightning Alarm
High Field Alarm Range:	0 to 20 kV/m
Very High Field Alarm Range:	0 to 20 kV/m
History Graph:	5 min, 15 min, 30 min, 1 hour, 2 hour, 4 hour, 8 hour, 24 hour Handles on the graph for zooming in.
Vertical Scales:	0.5 kV/m, 1 kV/m, 2 kV/m, 5kV/m, 7.5 kV/m, 10 kV/m, 15 kV/m, 20kV/m Handles on the graph for zooming in.

CS110

Electric Field Meter

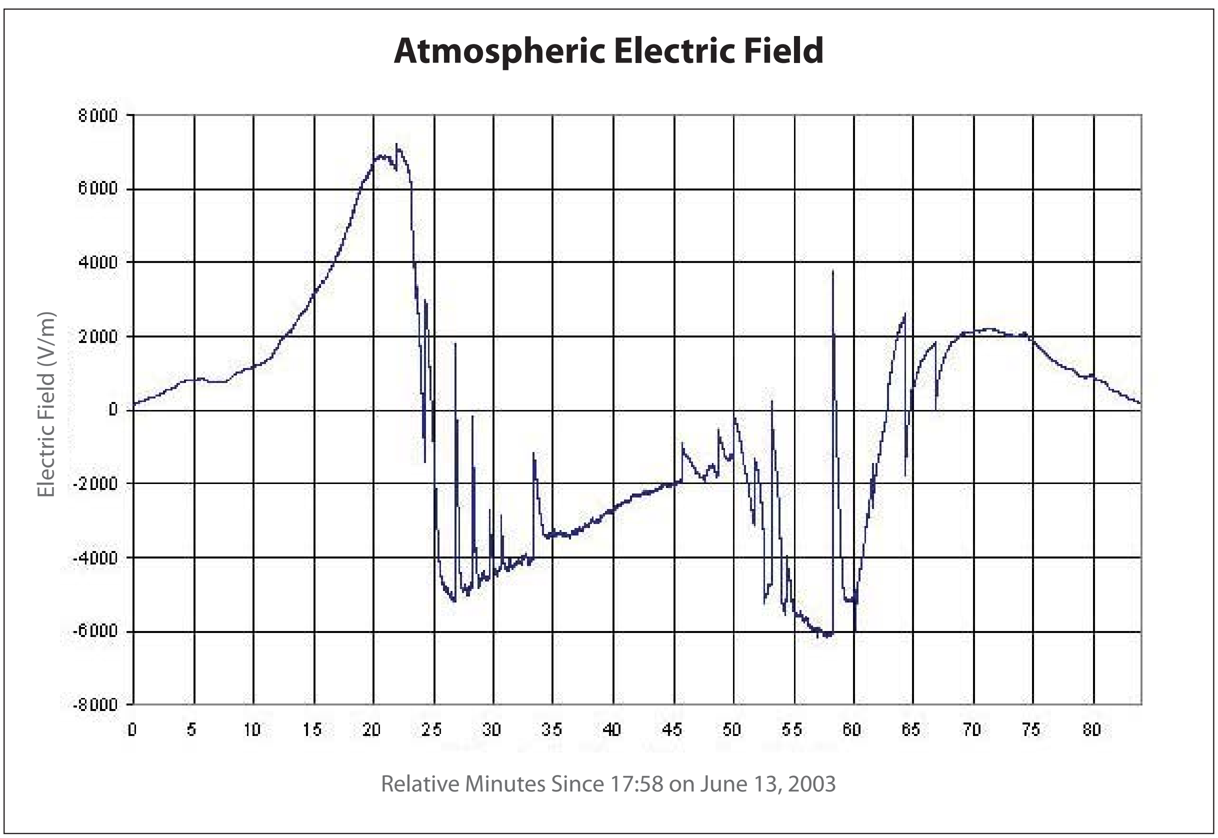
The CS110 Electric Field Meter measures the vertical component of the atmospheric electric field at the earth's surface. These atmospheric electric field measurements are useful for assessing the local lightning hazard and for thunderstorm research.

Reciprocating Shutter

Instead of the traditional rotating vane field mill, the CS110 uses a reciprocating shutter electrically connected to ground potential by a flexible stainless-steel strap. The strap operates below its fatigue limit, resulting in an ultra-reliable electrical ground connection to the shutter.

The reciprocating approach provides better low-frequency error performance than the traditional rotating vane field mill because it has a convenient zero-field (closed shutter) reference. The zero-field reference allows the CS110 to measure and then correct for electronic offset voltages, contact potentials, and leakage currents of each individual measurement (Patent Pending).

The CS110 also contains circuitry to measure and compensate for insulator leakage currents occurring on the charge amplifier input, eliminating measurement errors caused by fouled insulators. If insulator surfaces become conductive because of surface contamination, a leakage current compensation circuit applies an equal and opposite polarity current to the charge-amplifier input that prevents saturation of the electronics.



Data recorded by the CS110 during a thunderstorm in Cache Valley Utah is shown above. The rapid changes of the electric field are due to lightning discharges, some of which are hazardous cloud-to-ground strikes.

The CS110's internal datalogger can measure additional meteorological sensors—making the CS110 the center of a full weather station.

Using the CS110 as a Weather Station

The CS110 has sealed connectors for attaching meteorological sensors and three digital control ports for controlling external devices and/or triggering alarms. An embedded CR1000M datalogger module (ordered as p/n 18292) is required. The datalogger measures the sensors, processes the measurements, stores the data in tables, and can initiate communications. Communication options compatible with the CR1000 include direct connect, Ethernet, phone modems (land-line and cellular), radios, short haul modems, GOES satellite transmitters, and multidrop modems.

Programming

The CR1000's on-board programming language, CRBasic, provides data processing and analysis routines that support user control over sample (measurement) rates and setting of alarm conditions. LoggerNet Datalogger Support Software facilitates programming, communications, and data retrieval between the CS110 and a PC.

Logan High School in Logan Utah has installed a lightning warning system that includes the CS110. The CS110 is mounted to a CM110 10-ft stainless-steel tripod that sits on a roof next to the football field (left). Lights included in the system indicate the likelihood of lightning (right).

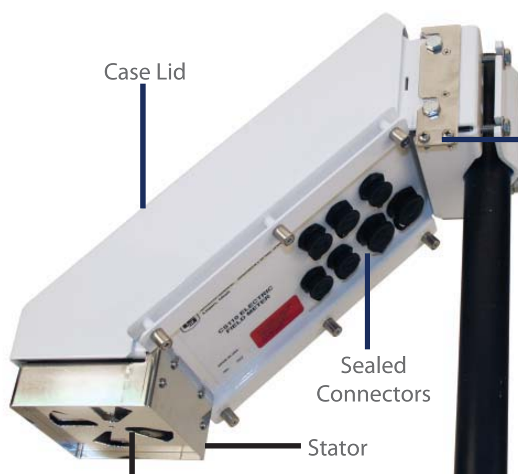
SG000 Strike Guard Lightning Sensor

The SG000 Strike Guard is an optical-coincidence lightning sensor that detects actual cloud-to-cloud and cloud-to-ground lightning strikes within a 20-mile radius. It is used in conjunction with the CS110 to create a complete lightning-threat measurement and analysis system.

The SG000 and CS110 are typically mounted on the same tripod or pole. They communicate via a fiber-optic link (FC100 interface and FC100CBL) that offers enhanced reliability in the lightning environment. For information about interfacing the SG000 with a CS110, visit www.campbellsci.com/sg000 or contact Campbell Scientific.

CS110 Specifications and Features

The overall gain of an electric field meter is dependent upon the electric-field enhancement or attenuation caused by a given site configuration. Consequently, it is necessary to reference a specific site configuration when discussing measurement performance. The CS110 is factory calibrated using a large (1 meter Hexagonal plates) parallel-plate electric-field calibrator. This parallel-plate configuration is equivalent to an outdoor unit mounted facing upward with the sense aperture flush with the surface of the earth. Inverted and elevated mounting is more practical and recommended for outdoor applications. Inverting and elevating the CS110 results in electric-field enhancement as compared to the parallel-plate configuration, with the enhancement dependent upon instrument height above the ground.



Electric Field Measurement Performance:

Parallel-Plate Configuration				*2 m CM10 Tripod Configuration*[2]			
Accuracy:	±1% of reading + 60 V m^{-1} offset[1]			*Accuracy:*	±5% of reading + 8 V m^{-1} offset[1]		
Measurement Range[3] *(V m^{-1})*	*Resolution (V m^{-1})*	*Sensitivity (µV/V m^{-1})*	*Noise (V m^{-1} RMS)*	*Measurement Range*[3] *(V m^{-1})*	*Resolution (V m^{-1})*	*Sensitivity (µV/V m^{-1})*	*Noise (V m^{-1} RMS)*
±(0 to 21,000)	3	12	4.0	±(0 to 2,200)	0.32	1.2	0.42
±(21,000 to 212,000)	30	118	18.0	±(2,200 to 22,300)	3.2	13	1.9

[1]Typical offset for clean electrodes is ≤|30 V m^{-1}| for the parallel-plate configuration, which is reduced by the field enhancement factor for typical inverted and elevated mounting configurations.

[2]Field enhancement due to typical inverted and elevated mounting requires additional site correction, estimated at ±5% accuracy when done in appropriate high field conditions. Practical outdoor CS110 electric field measurement accuracy is estimated at ±5% of reading + 8 V m^{-1} for the CS110 2 meter CM10 Tripod Site.

[3]The CS110 incorporates automatic gain ranging between two input ranges. The measurement is first tried on the lowest input range. If the signal is too large for the lowest range, the larger range is used.

CS110 Specifications and Features Continued

Datalogger: An embedded CR1000M datalogger module (ordered as p/n 18292) is required.

Standard Mounting: 2 m height on a tripod mast

Site Correction: Site correction factors available for several standard mounting configurations.

Programmability: CRBasic programming allows the selection of sample rate, data processing and storage options and setting output ports based on alarm conditions. LoggerNet includes the CRBasic editor and compiler.

Sample (Measurement) Rate: Programmable sample rate up to 5 samples per second, variable sample rates possible. Variable example: sample every 10 seconds until field exceeds threshold then sample once a second until field returns to normal.

Power Requirements:
- 11 to 16 Vdc; peak-current demand is 750 mA during motor operation.
- 7 mA @ 12 V = 0.08 W average power consumption at 1 sample per 10 seconds
- 60 mA @ 12 V = 0.7 W average power consumption at 1 sample per second
- 120 mA @ 12 V = 1.4 W average power consumption at 2 samples per second
- 300 mA @ 12 V = 3.6 W average power consumption at 5 samples per second

Cables (ordered separately):
- CS110CBL3-L power cable is required for the CS110 to operate; it connects the CS110 to its power source and can be used to communicate with an additional datalogger.
- CS110CBL1-L RS-232 cable connects the CS110 to a laptop, SG000 or other devices with an RS-232 port.
- CS110CBL2-L CS I/O cable connects the CS110 to the CS I/O port of a Campbell Scientific device such as the SG000, COM220, COM320, or NL100.

Communication: 1 RS-232 port; 1 CS I/O port used to interface with our peripherals such as a Voice Modem; digital control ports 1, 2, and 3 for alarm, SDI-12 communications, or asynchronous communications

Baud Rates: Selectable from 300 to 115,200 bps

ASCII Protocol: one start bit, one stop bit, eight data bits, no parity

Lightning Protection: Multi-stage transient protection on all external interfaces

Calibrations: NIST Traceable calibration certificate included

CE Compliance
Standards to which conformity is declared: BS EN61326:2002

Rugged Construction: Ultra-reliable metallic ground connection to reciprocating shutter (no wiping contact), brushless stepper motor, powder-coated aluminum case, Teflon insulators, and electro-polished 316L stainless-steel used for corrosion protection of critical exposed metallic parts

Connector/Compatible Sensors:

Connector Label	Compatible Sensors (one sensor per connector)
Temp/RH	HMP45C-LC
Wind	05103-LC, 05106-LC, 05305-LC, 034B-LC, 03001-LC
Solar	LI200X-LC pyranometer, CS100 barometer, CS106 barometer *(barometers connect to the CS110 via the 17460 cable; they should be housed in a separate enclosure such as the ENC10/12)*
Rain	CS700-LC, TB4-LC, TE525-LC, TE525WS-LC, TE525MM-LC

Easy Maintenance: The stator is easily removed for cleaning (proper cleaning does not invalidate calibration). The CS110 also incorporates extensive diagnostic self-checking for each measurement to reduce or eliminate scheduled maintenance. The self-checking monitors internal humidity, insulator cleanliness/power supply voltage, and verifies that CS110 components such as the charge amplifier and shutter open/close are functioning properly.

Zero Electric Field Cover (ordered separately): The 17642 Zero Electric Field Cover is used to check the electric field offset voltage of the CS110. If the measured electric field is ≥|60 V/m| with the Zero Electric Field Cover on, then inspection and cleaning of the electrode surfaces is recommended.

Operating Temperature Range :
-25° to 50°C standard, -40° to +85°C optional

RH Range: 0 to 100% RH

Dimensions: 6" x 6" x 17" (15.2 x 15.2 x 43.2 cm)

Mounting: vertical pipe 0.75" to 2.5" OD (1.91 to 6.35 cm)

Weight: 9 lbs (4 kg)

Warranty: The CS110 has a one year warranty against defects in materials and workmanship. Campbell Scientific does not warrant that the CS110 will meet customer's requirements or that its operation will be uninterrupted or error-free.

Atmospheric or local electric field conditions or different site characteristics may cause false information, late data, or otherwise incomplete or inaccurate data. The CS110 only measures conditions that make lightning more likely. Just as with weather forecasts, the CS110 measurements only help assess the probability of lightning. Lightning can occur causing personal injury, even death, or damage to property without any warning from the CS110.

Campbell Scientific is not liable for special, indirect, incidental, or consequential damages from the use, failure, or malfunction of the CS110. A full statement of the CS110's Warranty is contained in the CS110 Manual.

Annexe 2

Données météo

Jérôme Lovey, TD - 2012

Normes 1961-1990: Température moyenne maximale de l'air à 2m

Date de validation: 2012

Station	Alt. [m]	Jan	Fév	Mar	Avr	Mai	Jun	Jul	Aoû	Sep	Oct	Nov	Dec	Ann.
		[°C]												
Aadorf / Tänikon	539	1.9	4.0	8.2	12.3	17.2	20.4	22.9	22.1	18.9	13.2	6.6	2.8	12.5
Acquarossa / Comprovasco	575	5.1	6.6	10.3	13.9	18.0	22.0	24.4	23.5	20.1	14.9	9.0	6.3	14.5
Adelboden	1320	1.9	2.6	4.6	8.1	12.8	16.1	18.6	17.9	15.8	12.1	5.9	2.8	9.9
Aigle	381	3.5	5.5	9.2	13.5	17.6	21.1	24.0	23.0	19.7	14.8	8.6	4.3	13.7
Altdorf	438	3.9	5.5	9.3	13.3	18.2	20.9	23.0	22.2	19.2	14.3	8.5	4.6	13.6
Arosa	1840	-1.1	-0.6	1.7	4.6	9.1	12.8	15.8	15.1	12.8	8.9	2.7	0.0	6.8
Bad Ragaz	496	3.3	5.2	9.4	13.7	18.4	21.2	23.3	22.6	19.9	15.3	8.6	3.9	13.7
Basel / Binningen	316	3.5	5.9	10.0	14.1	18.4	21.7	24.1	23.4	20.3	14.8	8.2	4.4	14.1
Bern / Zollikofen	552	1.9	4.4	8.3	12.4	17.0	20.4	23.3	22.5	19.2	13.5	6.8	2.7	12.7
Biel/Bienne	433	2.8	5.3	9.5	14.0	18.6	21.8	24.6	23.8	20.5	14.4	7.6	3.8	13.9
Blatten, Lötschental	1535	1.2	3.1	5.4	8.4	13.0	16.9	20.1	19.1	16.8	12.7	6.1	1.5	10.4
Buchs / Aarau	386	2.2	4.7	9.2	13.5	18.2	21.6	24.2	23.4	20.0	13.9	7.0	3.1	13.4
Buffalora	1968	-2.5	-1.1	1.5	4.5	9.0	13.2	16.2	15.7	13.3	8.9	2.4	-2.1	6.6
Bullet / La Frétaz	1205	0.9	1.3	3.3	6.6	11.3	14.8	17.4	17.0	14.4	10.4	4.8	2.2	8.7
Chasseral	1599	-0.6	-0.9	0.3	3.2	7.9	11.3	14.0	13.3	11.0	8.0	2.6	0.6	5.9
Chaumont	1073	0.6	1.5	3.9	7.8	12.6	16.2	19.1	18.4	15.5	10.9	4.7	1.6	9.4
Chur	556	4.1	6.3	10.3	14.0	18.6	21.5	23.5	22.7	19.9	15.5	8.8	4.1	14.1
Château-d'Oex	985	2.1	3.8	6.9	10.8	15.5	18.7	21.5	20.7	18.0	13.4	6.8	2.6	11.7
Cimetta	1661	0.5	0.3	1.6	4.9	9.1	13.0	15.5	14.9	12.4	8.7	3.8	1.9	7.2
Col du Grand St-Bernard	2472	-5.0	-5.3	-4.2	-1.9	2.6	6.8	10.4	10.2	7.8	3.7	-1.6	-3.7	1.7
Davos	1594	-0.9	0.6	3.0	6.1	11.0	14.3	16.9	16.3	14.0	10.6	3.8	-0.4	7.9
Delémont	415	3.0	5.8	9.6	13.5	18.0	21.3	24.0	23.3	20.4	15.3	8.2	3.8	13.9
Disentis / Sedrun	1197	1.8	2.8	5.9	9.5	14.1	17.6	20.4	19.4	16.8	12.6	5.9	2.6	10.8
Ebnat-Kappel	620	2.4	4.4	7.9	12.0	17.0	20.1	22.7	21.8	19.0	14.0	7.5	3.2	12.7
Einsiedeln	910	1.2	2.5	5.2	9.0	13.9	17.1	19.6	18.7	16.1	11.9	6.0	1.9	10.3
Elm	958	1.0	3.2	6.0	9.8	15.0	17.8	19.7	18.9	16.5	12.8	5.8	1.6	10.7
Engelberg	1035	1.0	2.5	5.4	9.3	14.5	17.5	19.5	18.5	15.9	11.9	5.3	1.5	10.2
Evolène / Villa	1825	0.0	0.3	2.6	5.7	9.9	13.1	16.5	15.9	13.8	10.1	4.4	1.5	7.8
Fahy	596	2.6	4.2	7.5	11.4	15.7	19.2	21.8	21.2	18.0	13.3	7.4	3.8	12.2
Fey	737	2.6	5.2	9.3	13.7	18.0	21.3	23.6	22.6	19.5	14.5	7.5	3.5	13.4
Fribourg / Posieux	646	2.4	4.7	8.5	12.6	17.1	20.6	23.5	22.7	19.7	14.3	7.5	3.4	13.1
Genève-Cointrin	420	3.6	5.9	9.9	14.1	18.6	22.5	25.7	24.7	21.0	14.9	8.3	4.4	14.5
Glarus	516	2.0	3.7	7.9	12.6	17.4	20.2	22.2	21.2	18.3	13.7	7.4	3.1	12.5
Grimsel Hospiz	1980	-2.7	-2.6	-1.1	1.4	6.0	9.9	12.8	12.5	10.6	7.4	1.6	-1.4	4.5
Grono	382	5.5	7.6	11.8	15.3	19.3	23.1	26.0	25.0	21.7	16.4	10.0	6.7	15.7
Grächen	1550	2.3	3.3	5.3	8.7	13.1	17.0	20.0	19.2	16.6	12.2	6.0	2.8	10.5
Gstaad	1045	1.2	3.1	5.9	9.9	14.8	18.3	21.3	20.4	17.9	13.4	6.5	1.5	11.2
Gütsch ob Andermatt	2287	-3.8	-4.2	-3.3	-1.1	3.4	7.8	11.6	11.6	9.6	6.0	0.1	-2.4	2.9
Güttingen	440	2.1	4.1	8.5	13.0	17.7	20.9	23.2	22.3	19.0	13.0	6.7	3.0	12.8
Hallau	419	1.8	4.6	9.0	13.4	18.2	21.4	23.9	23.1	20.1	14.0	6.9	2.6	13.3
Hinterrhein	1611	-1.8	-0.9	1.6	4.7	9.6	14.2	17.2	16.4	13.9	9.5	2.8	-1.0	7.2
Interlaken	577	2.1	4.5	8.7	13.0	17.5	20.6	23.2	22.2	19.0	14.0	7.3	2.9	12.9
Jungfraujoch	3580	-10.5	-10.8	-10.0	-7.9	-3.7	-0.6	1.9	1.8	0.3	-2.5	-6.9	-9.1	-4.8
Koppigen	484	1.8	4.5	8.8	13.1	17.9	21.3	23.9	23.0	19.9	14.1	6.9	2.9	13.2
La Brévine	1048	0.1	1.8	4.3	8.2	13.0	16.5	19.4	18.7	16.3	12.3	5.5	0.9	9.8

Station	Alt. [m]	Jan	Fév	Mar	Avr	Mai	Jun	Jul [°C]	Aoû	Sep	Oct	Nov	Dec	Ann.
La Chaux-de-Fonds	1018	1.8	2.9	5.1	8.8	13.4	16.9	19.6	19.0	16.6	12.6	6.2	2.8	10.5
La Dôle	1669	-0.6	-0.8	0.4	3.5	8.1	12.1	15.2	14.6	12.4	8.8	2.9	0.6	6.4
Langnau i.E.	745	2.2	4.4	8.0	12.0	16.9	20.3	23.1	22.4	19.5	14.3	7.3	2.9	12.8
Le Moléson	1974	-1.4	-1.6	-0.8	1.4	5.8	9.3	12.3	12.1	10.1	7.5	2.6	0.1	4.8
Locarno / Monti	366	6.1	7.9	11.9	15.5	19.2	23.1	25.9	24.9	21.4	16.2	10.3	7.2	15.8
Lugano	273	6.1	7.8	11.6	15.1	18.9	22.9	25.8	24.7	21.4	16.5	10.6	7.1	15.7
Luzern	454	2.6	4.7	9.0	13.3	17.9	21.0	23.5	22.6	19.4	13.7	7.3	3.5	13.2
Magadino / Cadenazzo	203	5.4	7.9	12.3	16.1	20.1	23.9	26.5	25.4	21.9	16.5	10.2	6.3	16.0
Meiringen	588	1.7	4.2	8.2	12.6	17.3	20.0	22.1	21.1	18.4	13.7	7.3	2.2	12.4
Montana	1427	1.0	2.0	4.5	8.0	12.7	16.3	19.4	18.7	16.2	11.7	5.3	2.2	9.8
Montreux-Clarens	405	4.5	6.2	9.6	13.9	18.2	21.8	24.9	23.9	20.5	15.2	9.3	5.5	14.5
Napf	1403	0.4	0.5	2.3	5.4	10.3	13.6	16.4	15.7	13.2	9.8	4.0	1.5	7.8
Neuchâtel	485	2.4	4.7	8.7	13.1	17.5	20.9	23.9	23.2	19.5	13.5	7.1	3.3	13.2
Nyon / Changins	455	2.9	5.1	8.9	13.2	17.5	21.1	24.2	23.3	19.9	14.1	7.7	3.8	13.5
Passo del Bernina	2307	-4.5	-4.5	-2.6	0.6	5.4	9.8	13.0	12.2	9.5	5.3	-0.5	-3.3	3.4
Payerne	490	2.1	4.6	8.8	13.1	17.6	21.1	24.0	23.2	19.7	13.7	6.9	3.0	13.2
Pilatus	2106	-2.0	-2.3	-1.0	0.7	4.8	8.5	11.3	10.8	9.0	6.4	1.3	-0.7	3.9
Piotta	990	1.9	3.7	6.9	10.3	15.3	19.5	22.2	21.1	17.9	13.0	5.8	2.5	11.7
Piz Corvatsch	3305	-9.2	-9.9	-8.9	-6.8	-2.7	0.5	3.4	3.8	1.9	-1.0	-5.9	-8.3	-3.6
Plaffeien	1042	1.1	2.3	4.9	8.5	13.0	16.5	19.2	18.3	15.5	11.2	5.5	2.1	9.8
Poschiavo / Robbia	1078	2.9	3.9	6.9	10.8	14.9	18.7	21.3	20.4	17.3	12.8	7.1	4.1	11.8
Pully	455	3.5	5.2	8.7	13.0	17.3	21.1	24.2	23.1	19.5	14.1	7.9	4.3	13.5
Rheinfelden	300	2.9	5.5	9.9	14.5	18.9	22.0	24.7	23.9	20.6	14.6	7.7	3.8	14.1
Rünenberg	611	2.0	3.9	7.4	11.4	15.9	19.2	21.7	21.0	18.0	12.9	6.9	3.2	12.0
S. Bernardino	1638	-0.1	0.2	2.2	4.8	9.3	13.7	16.7	15.9	13.3	9.2	3.5	0.8	7.5
Salen-Reutenen	700	0.3	2.5	6.3	10.7	15.6	18.8	21.2	20.4	17.4	11.9	5.3	1.4	11.0
Samedan	1708	-2.2	-0.1	2.8	6.3	11.7	15.3	18.2	17.7	15.2	11.0	3.2	-1.8	8.1
Schaffhausen	438	1.6	4.3	8.8	13.3	17.9	21.1	23.6	22.8	19.4	13.3	6.5	2.5	12.9
Scuol	1303	-0.9	1.7	6.6	11.0	15.5	19.1	21.9	21.1	18.6	13.4	4.9	-0.6	11.0
Segl-Maria	1798	-0.8	0.4	2.7	5.0	9.2	13.7	16.6	15.9	13.8	9.4	3.7	0.0	7.5
Sion	482	3.4	6.2	10.8	15.4	19.8	23.4	26.1	24.8	21.2	16.0	8.8	3.9	15.0
St. Gallen	775	1.8	3.0	6.4	10.3	15.1	18.1	20.5	19.7	17.0	11.9	6.4	2.7	11.1
Sta. Maria, Val Müstair	1383	-0.3	2.0	5.6	9.4	14.3	18.3	20.8	19.5	16.5	11.4	4.2	0.5	10.2
Stabio	353	6.2	7.8	11.8	15.4	19.6	23.6	26.1	25.0	21.7	16.7	10.6	7.1	16.0
Säntis	2502	-5.1	-5.5	-5.1	-3.3	1.3	4.9	7.6	7.7	6.0	3.4	-1.6	-3.7	0.6
Ulrichen	1345	-1.4	0.8	3.8	7.4	12.8	17.0	20.4	19.6	17.2	12.4	4.8	-0.9	9.5
Vaduz	457	3.6	5.6	10.1	13.8	18.4	20.9	23.0	22.3	19.5	14.7	8.5	4.4	13.7
Visp	639	2.0	5.6	10.6	15.0	19.6	22.9	25.5	24.6	21.2	15.6	7.6	2.2	14.4
Weissfluhjoch	2690	-6.2	-6.6	-5.5	-3.1	1.6	5.0	8.7	8.9	7.0	3.8	-2.1	-4.8	0.6
Wynau	422	1.8	4.4	8.9	13.3	18.1	21.4	23.9	23.1	19.8	13.8	6.8	2.7	13.2
Wädenswil	485	1.8	4.0	8.2	12.7	17.5	20.7	23.1	22.1	18.9	13.2	6.9	3.1	12.7
Zermatt	1638	0.2	1.3	3.7	7.3	12.1	15.6	18.9	17.9	15.4	11.2	4.6	1.1	9.1
Zürich / Affoltern	443	2.1	4.6	8.9	13.2	18.0	21.1	23.7	22.9	19.6	13.8	7.1	3.1	13.2
Zürich / Fluntern	555	2.0	4.2	8.3	12.6	17.3	20.5	22.9	21.9	18.8	13.2	6.9	3.0	12.6
Zürich / Kloten	426	2.3	4.7	9.1	13.4	18.1	21.5	23.9	22.9	19.8	13.9	7.2	3.3	13.3

Normes standard 1961-1990: Température moyenne minimale de l'air à 2m

Date de validation: 2012

Station	Alt. [m]	Jan	Fév	Mar	Avr	Mai	Jun	Jul	Aoû	Sep	Oct	Nov	Dec	Ann.
		[°C]												
Aadorf / Tänikon	539	-4.6	-3.6	-1.0	1.9	5.8	9.4	11.1	10.8	8.1	4.6	-0.1	-3.2	3.3
Acquarossa / Comprovasco	575	-2.5	-1.6	0.9	3.9	7.6	10.6	12.8	12.2	9.9	6.0	1.3	-1.5	5.0
Adelboden	1320	-5.5	-5.2	-3.5	-0.4	3.6	6.4	8.6	8.5	6.5	3.5	-1.6	-4.3	1.4
Aigle	381	-2.8	-1.3	1.1	3.8	7.7	10.8	12.4	12.0	9.3	5.2	1.0	-2.0	4.8
Altdorf	438	-2.7	-1.7	0.6	4.1	7.9	11.1	13.2	12.8	10.3	6.3	1.7	-1.8	5.2
Andermatt	1442	-8.2	-7.8	-5.0	-1.3	2.8	5.4	7.6	7.4	4.9	1.6	-3.8	-7.5	-0.3
Arosa	1840	-6.8	-6.9	-5.2	-2.2	1.8	5.0	7.4	7.3	5.3	2.2	-2.9	-5.8	-0.1
Bad Ragaz	496	-3.3	-1.8	1.1	4.4	8.4	11.5	13.4	13.2	10.7	6.3	1.3	-2.6	5.2
Basel / Binningen	316	-1.9	-0.7	1.7	4.4	8.1	11.1	13.0	12.8	10.4	6.6	2.0	-0.8	5.6
Bern / Zollikofen	552	-3.7	-2.4	-0.1	3.0	6.9	10.1	12.1	11.7	9.0	5.3	0.5	-2.6	4.2
Biel/Bienne	433	-2.4	-1.3	0.9	4.1	8.2	11.6	13.6	13.1	10.3	6.4	1.8	-1.2	5.4
Blatten, Lötschental	1535	-7.7	-7.5	-5.1	-1.7	2.4	5.1	7.2	6.9	5.0	1.9	-3.3	-6.6	-0.3
Buchs / Aarau	386	-2.5	-1.6	0.5	3.6	7.6	10.8	12.5	12.0	9.5	6.1	1.6	-1.3	4.9
Buffalora	1968	-15.8	-15.1	-11.8	-6.8	-1.6	1.7	3.5	3.2	0.7	-3.5	-9.9	-14.7	-5.8
Bullet / La Frétaz	1205	-4.9	-4.4	-2.4	0.2	4.0	7.1	9.4	9.2	7.1	3.9	-1.4	-3.7	2.0
Chasseral	1599	-5.5	-5.7	-4.1	-1.9	2.2	5.3	7.7	7.6	5.6	2.9	-2.2	-4.5	0.6
Chaumont	1073	-4.9	-4.3	-2.3	0.9	4.9	7.8	10.0	9.8	7.7	4.2	-0.9	-3.7	2.4
Chur	556	-3.9	-2.4	0.4	3.4	7.2	10.2	12.1	11.8	9.3	5.3	0.3	-3.3	4.2
Château-d'Oex	985	-6.3	-5.3	-2.7	0.6	4.7	7.9	9.9	9.4	7.0	3.2	-1.8	-5.3	1.8
Cimetta	1661	-4.3	-4.6	-2.6	-0.3	3.6	7.3	9.8	9.6	7.5	3.9	-0.9	-3.4	2.1
Col du Grand St-Bernard	2472	-10.5	-10.6	-9.5	-6.8	-2.3	1.0	3.8	3.8	1.9	-1.3	-6.8	-9.2	-3.9
Davos	1594	-9.6	-9.3	-6.6	-2.9	1.2	4.1	6.1	6.0	3.5	0.1	-5.0	-8.4	-1.7
Delémont	415	-3.4	-2.0	0.2	3.0	7.0	10.3	11.9	11.7	9.2	5.6	0.8	-2.2	4.3
Disentis / Sedrun	1197	-5.1	-4.6	-2.5	0.6	4.5	7.3	9.5	9.3	7.2	3.9	-1.1	-4.2	2.1
Ebnat-Kappel	620	-5.4	-4.3	-1.6	1.7	5.6	9.1	11.2	10.8	8.0	4.2	-0.6	-4.4	2.9
Einsiedeln	910	-6.4	-5.4	-2.7	1.0	5.1	8.4	10.7	10.2	7.6	3.8	-1.2	-5.1	2.2
Elm	958	-5.2	-4.4	-2.0	1.4	5.4	8.4	10.7	10.4	7.9	4.2	-0.9	-4.3	2.6
Engelberg	1035	-6.5	-5.5	-3.1	0.1	4.1	7.0	9.2	8.9	6.6	3.1	-1.9	-5.6	1.4
Evolène / Villa	1825	-6.6	-6.6	-5.0	-2.4	1.7	4.4	6.9	7.0	5.1	2.1	-2.9	-5.3	-0.1
Fahy	596	-3.2	-2.2	0.2	2.9	6.7	9.7	11.8	11.5	9.2	5.4	0.7	-2.2	4.2
Fey	737	-2.6	-1.4	0.9	4.0	8.0	11.2	13.2	12.9	10.6	6.9	1.9	-1.4	5.4
Fribourg / Posieux	646	-4.0	-2.8	-0.5	2.5	6.4	9.7	11.6	11.3	8.6	4.9	0.2	-2.9	3.8
Genève-Cointrin	420	-1.9	-0.9	0.8	4.1	8.0	11.3	13.3	13.0	10.3	6.6	2.1	-0.5	5.5
Glarus	516	-4.0	-2.7	-0.1	3.2	7.0	10.0	12.1	11.8	9.3	5.3	0.5	-3.3	4.1
Grimsel Hospiz	1980	-8.8	-8.8	-7.3	-4.4	0.0	3.2	5.6	5.6	3.9	1.1	-4.0	-7.6	-1.8
Grono	382	-0.6	0.6	3.3	6.8	10.3	13.4	15.8	15.3	12.6	8.4	3.5	0.4	7.5
Grächen	1550	-6.5	-6.3	-4.4	-1.2	2.9	6.1	8.6	8.2	5.9	2.5	-2.7	-5.6	0.6
Gstaad	1045	-9.1	-8.0	-5.3	-1.2	2.9	5.7	7.8	7.5	5.1	1.3	-3.8	-7.8	-0.4
Gütsch ob Andermatt	2287	-9.3	-9.5	-8.2	-5.7	-1.5	1.6	4.2	4.2	2.4	-0.5	-5.6	-8.1	-3.0
Güttingen	440	-3.1	-2.3	0.1	3.1	7.1	10.5	12.4	12.1	9.6	5.8	1.1	-2.0	4.5
Hallau	419	-3.7	-2.6	0.1	3.5	7.6	10.8	12.4	11.9	9.1	5.1	0.6	-2.5	4.4
Hinterrhein	1611	-12.1	-12.0	-8.7	-3.7	0.9	3.4	5.4	5.4	3.0	-0.7	-6.2	-10.7	-3.0
Interlaken	577	-4.1	-3.1	-0.7	2.6	6.5	9.7	11.9	11.4	8.7	4.6	0.0	-3.1	3.7
Jungfraujoch	3580	-16.6	-16.8	-15.7	-13.4	-9.0	-5.9	-3.4	-3.3	-5.1	-7.6	-12.8	-15.3	-10.4
Koppigen	484	-3.9	-2.6	-0.1	3.1	7.1	10.4	12.1	11.8	9.1	5.4	0.8	-2.4	4.2

Station	Alt. [m]	Jan	Fév	Mar	Avr	Mai	Jun	Jul [°C]	Aoû	Sep	Oct	Nov	Dec	Ann.
La Brévine	1048	-11.2	-9.2	-7.1	-3.2	0.4	3.1	5.5	5.4	2.9	-0.5	-5.5	-9.7	-2.4
La Chaux-de-Fonds	1018	-6.4	-5.5	-3.5	-0.1	3.6	6.6	8.7	8.3	6.1	2.9	-2.0	-4.9	1.2
La Dôle	1669	-5.9	-5.8	-4.5	-2.0	1.9	5.1	7.7	7.6	5.8	2.7	-2.5	-4.8	0.4
Langnau i.E.	745	-4.9	-3.6	-1.1	2.1	6.2	9.4	11.5	11.0	8.4	4.6	-0.2	-3.8	3.3
Le Moléson	1974	-6.7	-6.8	-5.7	-3.4	0.6	3.8	6.3	6.3	4.6	2.0	-2.9	-5.4	-0.6
Locarno / Monti	366	0.2	1.2	3.9	7.2	10.8	14.1	16.6	16.0	13.3	9.0	4.2	1.2	8.1
Lugano	273	0.1	1.3	3.9	7.2	11.0	14.2	16.7	16.0	13.3	9.1	4.4	1.0	8.2
Luzern	454	-3.1	-2.0	0.4	3.7	7.9	11.1	13.3	13.0	10.1	5.9	1.1	-1.9	5.0
Magadino / Cadenazzo	203	-4.0	-1.8	1.2	5.0	9.2	12.7	14.9	14.2	10.9	5.9	0.8	-2.8	5.5
Meiringen	588	-5.5	-4.1	-1.4	2.0	5.8	8.7	10.7	10.3	7.9	4.1	-0.7	-4.5	2.8
Montana	1427	-5.5	-5.5	-3.7	-0.7	3.5	6.6	8.9	8.7	6.9	3.7	-1.3	-4.2	1.5
Montreux-Clarens	405	-0.8	0.3	2.4	5.5	9.5	12.8	15.1	14.7	12.0	8.0	3.3	0.0	6.9
Napf	1403	-4.9	-4.7	-2.9	-0.6	3.6	6.6	9.3	9.1	7.1	4.1	-1.1	-3.6	1.8
Neuchâtel	485	-1.4	-0.4	1.7	4.8	8.7	11.9	14.1	13.7	11.2	7.4	2.7	-0.3	6.2
Nyon / Changins	455	-2.1	-0.8	1.1	4.1	7.9	10.9	13.1	12.8	10.2	6.5	2.1	-0.9	5.4
Passo del Bernina	2307	-10.9	-11.1	-9.2	-5.8	-1.3	2.4	5.2	5.0	2.8	-0.8	-6.3	-9.9	-3.3
Payerne	490	-3.3	-2.1	0.0	3.0	6.8	10.0	11.9	11.6	9.0	5.3	0.9	-2.1	4.3
Pilatus	2106	-7.5	-7.6	-6.4	-4.4	-0.1	2.8	5.4	5.2	3.5	1.2	-4.1	-6.4	-1.5
Piotta	990	-4.8	-3.8	-1.2	2.1	6.0	9.1	11.4	11.0	8.5	4.4	-0.6	-3.6	3.2
Piz Corvatsch	3305	-14.9	-15.1	-14.2	-11.3	-7.0	-3.8	-1.2	-1.1	-2.8	-5.5	-10.9	-13.7	-8.5
Plaffeien	1042	-4.6	-3.9	-1.8	1.0	4.9	8.0	10.3	10.2	7.7	3.9	-0.8	-3.7	2.6
Poschiavo / Robbia	1078	-7.5	-6.5	-3.1	0.7	4.1	6.8	8.9	8.5	6.2	2.2	-2.4	-6.0	1.0
Pully	455	-0.5	0.5	2.7	5.6	9.4	12.7	15.1	14.6	12.1	8.4	3.7	0.6	7.1
Rheinfelden	300	-3.0	-1.9	0.2	3.0	7.1	10.4	12.3	11.9	9.3	5.9	1.0	-1.9	4.5
Rünenberg	611	-3.1	-2.0	0.7	3.6	7.5	10.6	12.7	12.4	9.9	6.0	1.3	-1.9	4.8
S. Bernardino	1638	-8.3	-8.0	-5.7	-2.3	1.5	5.0	7.3	6.9	4.6	0.9	-4.0	-7.3	-0.8
Salen-Reutenen	700	-4.5	-3.6	-0.8	2.3	6.4	9.7	11.7	11.3	8.9	4.9	0.0	-3.4	3.6
Samedan	1708	-18.0	-17.2	-11.9	-5.5	-1.1	1.5	3.0	2.8	-0.1	-4.2	-10.6	-16.1	-6.5
Schaffhausen	438	-3.3	-2.3	0.6	3.9	7.9	10.9	12.5	12.1	9.5	5.7	1.1	-1.9	4.7
Scuol	1303	-8.9	-7.8	-4.7	-0.9	3.1	6.0	8.0	7.8	5.1	1.1	-4.0	-8.1	-0.3
Segl-Maria	1798	-12.8	-12.6	-9.3	-4.4	0.3	3.6	5.6	5.5	3.0	-0.9	-5.9	-10.3	-3.2
Sion	482	-3.8	-2.1	0.8	4.0	7.8	10.8	12.5	12.0	9.0	4.5	-0.1	-3.3	4.3
St. Gallen	775	-3.8	-2.9	-0.1	2.8	6.8	9.9	12.1	11.8	9.3	5.4	0.7	-2.8	4.1
Sta. Maria, Val Müstair	1383	-6.8	-6.4	-3.8	-0.1	4.1	7.3	9.4	9.0	6.5	2.6	-2.4	-5.9	1.1
Stabio	353	-4.9	-3.7	-0.3	3.4	7.6	11.0	13.3	12.9	10.1	5.6	0.4	-3.5	4.3
Säntis	2502	-10.3	-10.6	-9.5	-6.9	-2.6	0.4	2.8	2.9	1.2	-1.2	-6.6	-9.1	-4.1
Ulrichen	1345	-13.1	-12.2	-7.7	-2.7	1.4	4.1	5.9	5.6	3.1	-0.9	-6.6	-11.8	-2.9
Vaduz	457	-3.5	-2.0	1.2	4.0	8.0	10.9	12.7	12.6	10.0	5.7	1.0	-2.6	4.8
Visp	639	-5.7	-3.8	-0.5	2.5	6.2	9.1	10.7	10.2	7.6	3.2	-1.3	-5.0	2.8
Weissfluhjoch	2690	-11.8	-12.1	-10.9	-8.1	-3.7	-0.6	1.8	2.1	0.3	-2.4	-7.6	-10.4	-5.3
Wynau	422	-3.2	-2.4	-0.4	2.8	6.8	10.0	11.8	11.4	8.9	5.6	1.0	-2.0	4.2
Wädenswil	485	-3.2	-2.1	0.4	3.7	7.7	11.0	13.1	12.6	10.0	6.1	1.5	-1.9	4.9
Zermatt	1638	-8.4	-7.8	-5.5	-2.2	2.1	4.8	6.8	6.7	4.2	0.7	-4.0	-7.1	-0.8
Zürich / Affoltern	443	-3.7	-2.7	-0.3	2.9	6.8	10.0	11.9	11.6	8.8	5.2	0.7	-2.2	4.1
Zürich / Fluntern	555	-2.8	-1.9	0.6	3.7	7.7	10.8	12.8	12.4	10.0	6.2	1.4	-1.7	4.9
Zürich / Kloten	426	-4.1	-3.2	-0.7	2.5	6.4	9.7	11.6	11.2	8.5	4.9	0.2	-2.8	3.7

Températures les plus basses enregistrées au Mont Säntis

Année	Température [°C]
2000	**-18.6**
2001	**-26.0**
2002	**-17.4**
2003	**-21.3**
2004	**-18.8**
2005	**-24.0**
2006	**-22.3**
2007	**-19.8**
2008	**-19.0**
2009	**-22.0**
2010	**-21.2**
2011	**-18.2**

Annexe 3

Rapport du travail sur les simulations au moyen d'éléments finis

Jérôme Lovey, TD - 2012

NUMERICAL SOLUTION OF THE LEADER PROGRESSION MODEL BY MEANS OF THE FINITE ELEMENT METHOD

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ABSTRACT

As known the lightning incidence of a vertical structure is related to the physical processes involved in the final stage of the progression of the downward lightning leader to the structure and upward streamers, in case downward flashes are taken into account. Within this context, the paper presents and discusses a numerical implementation based on the Finite Element Method (FEM) of the Leader Progression Model (LPM): LPM-FEM. The obtained results are compared with those of the original implementation of the LPM based on the charge simulation method and the relevant differences analyzed and discussed.

1 INTRODUCTION

Designers of lightning protection system (LPS) need to evaluate the lightning incidence of the structure to be protected. For instance, such an information is of crucial importance for engineers who must select the insulation level of an overhead power line against lightning flashover rate, in order to meet the reliability criteria set for the system [1-4].

For such an evaluation, only first strokes of negative downward flashes are generally taken into account in view of the following reasons: i) upward flashes occur mainly from very tall structures or mountain-top installations; ii) the majority of downward flashes are of negative polarity (except for tall structures and in the few regions with frequent winter thunderstorms) and iii) the majority of subsequent return stroke peak currents are smaller than the corresponding first stroke one [5].

The lightning incidence of a vertical structure is estimated by means of its so-called lightning exposure, which is related to the physical processes involved in the final stage of the progression of the downward lightning leader to the structure and of upward streamer injection. In general, in this type of studies, the downward motion of a lightning leader approaching ground is assumed to continue unperturbed, unless critical field conditions develop, allowing a juncture with a nearby vertical object generally called final jump.

Several researchers have contributed to the development of engineering models aimed at representing this complex phenomenon; nowadays it is generally accepted that the models applied to calculate lightning incidence on transmission can be grouped in two main categories:

- conventional models based on the so-called electrogeometric model (EGM) (e.g. [6-8]), which are based on the preliminary work of Golde [9];
- more recent models based on the simulation of the leader progression (LPM, [10-12]) and other similar approaches (e.g. [13-15]).

In addition to the above mentioned approaches, it is worth mentioning that a more recent representation of the lightning upward connecting leader inception has been proposed in [16] and a specific discussion about the final connecting stage between downward and upward leaders has been presented [17].

As known, the basic concept of the EMG is that it takes into account a downward lightning leader only, without taking into consideration the upward (positive) leader from the structure. Additionally, it assumes that the downward leader channel is perpendicular to the ground plane and that the flash will stroke the tower if its prospective ground termination point lies within the so-called ‘attractive radius’. The attractive radius depends on several factors, such as: charge of the leader, its distance from the structure, type of structure (vertical mast or horizontal conductor), structure height.

On the other hands, the LPM has been developed from knowledge of discharge physics on long air gaps under switching surge conditions with the hypothesis of a good similarity between propagation and inception of downward and upward leaders at laboratory tests and lightning phenomena in spite of the 10x difference in scale. In [10-12] the downward propagation of the leader is determined using the known charge simulation method [18] in which fictitious line charges, which allow to provide particular solutions of Laplace and Poisson’s equations satisfying specific boundary conditions, are used to calculate the leader electric field at any point.

The use of the charge simulation method for the solution of the LPM can be replaced by numerical methods like Finite Difference (FD) or Finite Elements (FEM), which allow a more straightforward treatment of:

- boundary conditions of the problem;
- structure exposition;
- leader charge positions;
- ascending leader starting point;
- presence of non-flat terrain.

On the base of these advantages, the paper presents a numerical algorithm based on the use of the FEM [19] for the LPM calculation. In particular, the paper aims at providing the details relevant to the problem formulation and boundary condition treatment. In this respect, it is worth noting that all the general assumptions used in the original LPM were maintained in the LPM-FEM simulations.

Comparison with results obtained by solving the LPM by means of the charge simulation method (e.g. Dellera and Garbagnati [10-12]) are also provided and discussed.

The structure of the paper is the following: section 2 illustrates the problem formulation with reference to the representation of the various domains, boundary conditions, earthed structure, downward and upward leader as well as the final jump. Section 3 illustrates the results obtained by applying the proposed LPM-FEM model to a 30 m vertical structure as well as their comparison with the results obtained in [10-12]. Section 4 concludes the paper with the main final remarks.

2 PROBLEM FORMULATION

2.1 General aspects related to the main equations and boundary conditions

As discussed in [10-12], the representation of both upward and downward leaders propagation is determined by means of the solution of subsequent steady-state electrostatic problems. In the considered domain, the leaders charges represent the source of the problem and the earthed structure, together with the ground zero-potential and the cloud charge distribution, the boundary conditions.

As known, the problem consists in the calculation of the electrostatic field into a dielectric material region (air) ($\Omega \in \Re^3$) provided by the solution of the Poisson's equation:

$$-\nabla\left(\varepsilon_0 \nabla \mathbf{V} - \mathbf{P}\right) = \rho \qquad (1)$$

where, $\mathbf{V}$ is the electric scalar potential, ε_0 is the permittivity of vacuum (indeed, we assume that the material in which the problem is formulated is air), $\mathbf{P}$ is the electric polarization and ρ the space charge density.

The adopted FEM model solves (1) as a function of the so-called dependent variables (namely, the variables that the partial differential equation (1) is formulated for) that, in our problem formulation, are the three components V_x, V_y and V_z of the electric scalar potential $\mathbf{V}$ [20].

In correspondence of the exterior boundaries $\partial\Omega$ that define Ω, the following different conditions are of interest for the LPM solution:

- electric potential: $\mathbf{V}_{\partial\Omega}$;
- ground, $\mathbf{V}_{\partial\Omega}=0$;
- surface charge density: $\rho_{\partial\Omega}$;
- zero charge: $\rho_{\partial\Omega}=0$.

Concerning the interior boundaries of Ω, as we assume such a domain to be characterized by a uniform dielectric medium (air), two possible conditions are of interest, namely: i) representation of leaders charges ρ by means of linear distributed charge densities $\rho_{\partial^2\Omega}$ and ii) representation of the earthed structure by means of grounded edges $V_{\partial^2\Omega} = 0$.

2.2 Main domain representation

The domain Ω (see Fig. 1) is divided into two sub-domain: the first one, Ω_1, consists of a cylindrical region of air characterized by 5 km radius and 2 km height; the second one, Ω_2, is still a cylindrical region of air but of a reduced size in order to surround the earthed structure. As both upward leader and final jump takes place into a region of space close to the earthed structure, the aim of Ω_2 is to provide a control volume in which a more refined finite-element mesh size can be applied. Ω_2 is characterized by the following dimensions: 0.5 km radius and 0.75 km height.

In [10-12], the cloud charge (Q_c) has been assumed composed by different concentric charge rings, located at 2 km height, aimed at providing a simplified representation of a constant surface charge density. In our simulation such a source has been directly represented by means of a constant surface charge density in correspondence of the top circular boundary of Ω_1 (see Fig. 1).

As known, the values of Q_c present a large dispersion (e.g. [21,22]). In our simulations it has been assumed $Q_c = -4$ C [10-12] and the relevant constant surface charge density $\rho_{\partial\Omega}$ is therefore given by the following:

$$\int_{\partial\Omega} \rho_{\partial\Omega} = Q_0 \xrightarrow{\rho_{\partial\Omega}=\text{const.}} \rho_{\partial\Omega} = \frac{-4C}{\pi \cdot \left(5 \cdot 10^3 m\right)^2} = = -5.093 \cdot 10^{-2} \left[\mu C/m^2\right] \qquad (2)$$

In Fig. 1 the top surface of Ω_1 is a boundary condition in which a constant charge density, with value $\rho_{\partial\Omega}$ provided by (2), has been assumed.

Concerning the side surfaces of Ω_1, we have assumed a boundary condition that allows to unconstraint the electric scalar potential, such a condition is satisfied assuming $\rho_{\partial\Omega}=0$ (see Fig. 1).

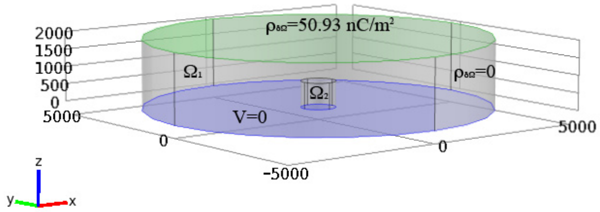

Fig. 1 Representation of domains Ω_1 and Ω_2 and external boundaries.

2.3 Earthed structure representation

In order to compare the results with those published in [10-12], we have assumed the earthed structure represented by a thin wire vertical mast. Such a structure is an interior boundary of Ω_2 in which we have imposed a grounded (**V**=0) edge. It is worth observing that, compared to the charge simulation method, the direct adoption of such a boundary condition avoids the use of the so-called virtual charges, used in the original LPM, in order to obtain a profile of the zero-level electric potential as close as possible to the earthed structure. It is also important to note that, in principle, the charge simulation method would require a continuous modification of the virtual charges (both position and value) as the constant electric potential profiles in correspondence of the earthed structure evolves with the progression of downward and upward leaders. On the other hands the adoption of a boundary condition that forces the potential of the earthed structure to zero inherently allows to obtain a more correct representation of the problem.

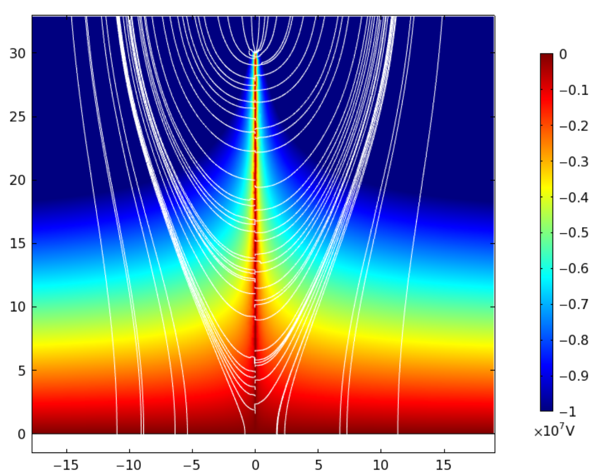

Fig. 2 Voltage profiles and electric field streamlines into the y-z plane of Fig. 1 for a grounded 30 m high vertical earthed structure, assuming as source the cloud charge only.

Fig. 2 shows the voltage profiles and the electric field streamlines into the y-z plane of Fig. 1 for a 30 m height vertical earthed structure assuming, as a source, the cloud Q_c charge only.

2.4 Downward leader representation and propagation criteria

The downward leader is represented by means of a linear charge distribution which value is determined as the ration between the total charge correlated to the lightning current, Q_{fp}, and the average total leader length of 2 km (distance between the simplified cloud charges and the ground, that corresponds to the height of Ω_1). In order to compare the results with those of [10-12], we have adopted the same expression that provides the average value of Q_{fp} as a function of the lightning waveshape first peak current expressed in kA [23,24]:

$$Q_{fp} = 76 \cdot I^{0.68} \cdot 10^{-3} \left[C\right] \tag{3}$$

Therefore, in correspondence of the interior boundary $\rho_{\partial^2\Omega}$ of Ω_1 that simulates the downward leader, the following condition has been imposed:

$$\rho_{\partial^2\Omega}^{down} = 38 \cdot I^{0.68} \left[\mu C/m\right] \tag{4}$$

It is worth adding that, in agreement with [10-12], the most advanced part of the downward leader (leader tip) is characterized by a value of linear charge density $\rho_{\partial^2\Omega}^{down}$ uncorrelated to the lightning current and assumed equal to 100 μC/m.

As known, the propagation direction of the downward leader depends to the phenomenon associated to the negative streamers that start from the leader tip (e.g. [16]). These streamers tends to follow the streamlines of the electric fields and, therefore, like in the original LPM, it has been assumed that the direction of the downward leader corresponds to the one of the maximum gradient of the electric potential, namely the direction of the maximum electric field streamline, estimated in correspondence of a domain in front of the streamer zone. The extension of such a domain is assumed equal to a region in front of the downward leader tip in which the electric field is above 300 kV/m.

In view of the above, the estimation of the maximum gradient of the electric potential is performed in correspondence of a hemisphere, centered in correspondence of the leader tip, which radius can range from few tens to few meters (more precisely from 20 m to 3 m) as a function of the streamer zone extension. Fig. 3a shows the top view of the electric potential in correspondence of such a hemisphere (20 m diameter) for a downward leader corresponding to a peak current of 20 kA at 50 m from the ground and 25 m from the vertical structure. Fig. 9b shows the same distribution but making reference to the spherical coordinate system that parameterize the hemisphere as a function of the latitude (ϑ) and longitude (φ). The white zone in Fig. 9b indicates the region corresponding to the maximum electric field gradient. It can be noted in Fig. 3a the asymmetrical distribution of the electric potential as well as, in Fig. 3b, the relevant maximum gradient region located into (ϑ,φ) coordinate different from (0,π).

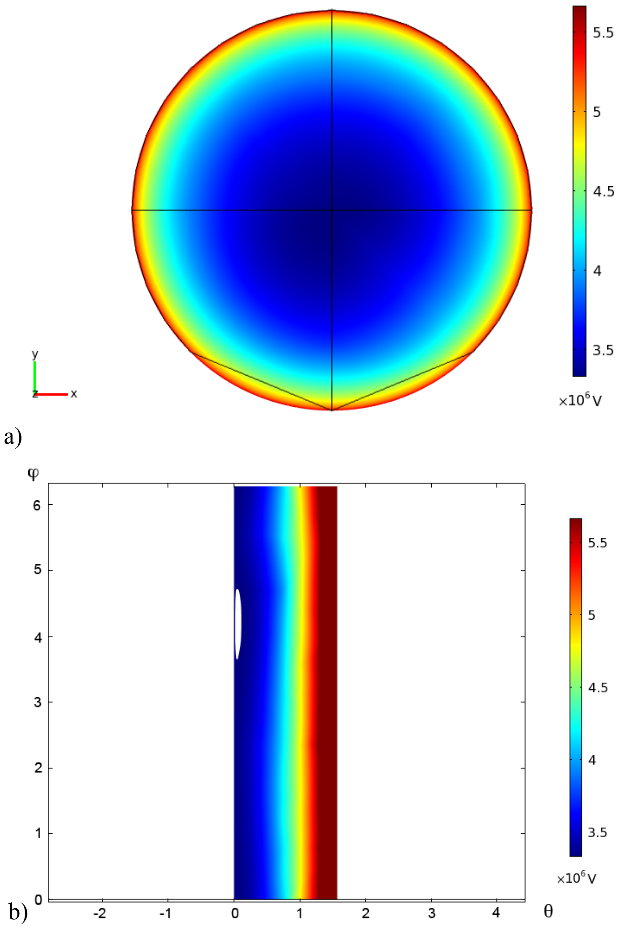

Fig. 3 Electric potential profiles in correspondence of the hemisphere control surface with 20 m diameter for a downward leader corresponding to a peak current of 20 kA. Leader tip at 50 m from the ground and 25 m from the earthed structure. a) top view in the *xy* plane of the hemisphere control surface electric potential; b) electric potential of the hemisphere represented in spherical coordinate system.

Fig. 4 shows the electric potential iso-surfaces associated to a downward leader corresponding to a peak current of 20 kA. At this stage of the simulation (downward leader at 360 m from ground) the inception conditions for the formation of the upward leader from the 30 m structure have not yet been reached (see next paragraph). It can be seen the deformation of the electric potential iso-surfaces due to: i) the different linear charge density of the leader channel compared to the leader tip ($1.5\cdot10^7$ V iso-surface) and ii) the presence of the earthed structure ($0.01\cdot10^7$ V iso-surface).

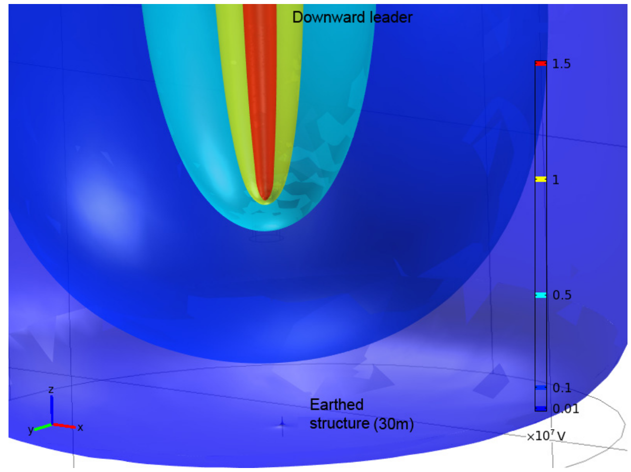

Fig. 4 Electric potential iso-surfaces associated to a downward leader corresponding to a peak current of 20 kA. Downward leader at 360 m from the ground.

2.5 Upward leader representation and propagation criteria

This section illustrates and discusses two main aspects concerning the upward leader, namely: inception and consequent propagation.

As discussed in the introduction, the LPM is based on the similarity between laboratory tests and lightning phenomena of the propagation and inception of downward and upward leaders. Concerning the upward leader inception, on the basis of the observations of [25,26], Dellera and Garbagnati assume that the conditions for the inception of positive leaders from earthed structures is substantially not influenced by the earthed electrode size, up to the so called 'critical radius'. The critical radius, assumed in [10-12] in the order of few tens of centimeters, defines therefore a region of space surrounding the earthed structure above which we can calculate the electric field in order to determine the upward leader inception. Such a calculation has been implemented by means of a so-called 'control-surface' Σ that surrounds the earthed structure. Fig. 5 shows the norm of the electric field in correspondence of Σ with the same conditions used to obtain Fig. 4.

For each point $P(x,y,z)\in\Sigma$ the value of the norm of the electric field is compared to the threshold value that provides the upward leader inception. Compared to the model of Dellera and Garbagnati, in which the starting point of the upward leader was assumed a-priori in correspondence of the position of the virtual charges of the charge-simulation method, the model here presented allows the estimation of the inception position into the whole area that surrounds the earthed structure.

Concerning the inception critical field, in order to provide a comparison with the same conditions of [10-12], we have adopted the value derived from [2] and reported for convenience in Fig. 6.

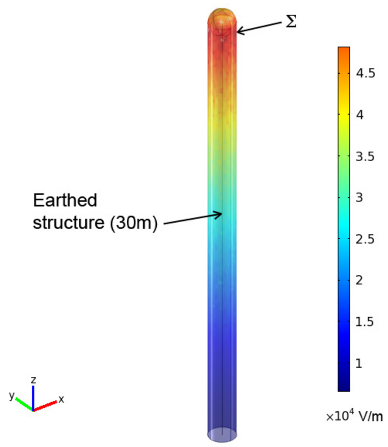

Fig. 5 Norm of the electric field in correspondence of the control surface surrounding the earthed structure. Downward leader corresponding to a peak current of 20 kA located at 360 m from the ground.

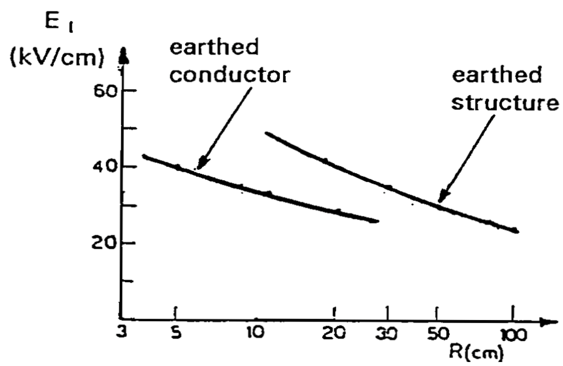

Fig. 6 Critical leader inception electric field as a function of the electrode radius. Adapted from [2].

Concerning the upward leader propagation, it has been assumed that the ratio between downward and upward leader propagation speeds is constant and equal to 4. Therefore, as the spatial propagation steps of the downward leader are of 10 m, the corresponding upward leader ones are of 2.5 m. The upward positive leader charge has been assumed independent from the downward leader charge and equal to 50 μC/m. The criteria used for the calculation of the propagation direction of the upward leader are the same of the ones adopted for the downward leader.

2.6 Final jump

The progressive propagation of downward and upward leaders could evolve into a so-called final if, in the space region between the two leaders, it is possible to identify a path characterized by a voltage gradient larger than the streamer gradient value, namely an electric field in the order of 500 kV/m (e.g. [13,17]).

Such a path estimation has been implemented as follows: for each electric field streamline connecting the two leaders it has determined whether the electric field exceeds the value of 500 kV/m along the overall streamline length. Fig. 7 shows an example of such an estimation concerning the case of a downward leader corresponding to a peak current of 20 kA located at 23 m from the earthed structure. In particular, Fig. 7a shows the electric field norm iso-surfaces together with the electric field streamlines, Fig. 7b shows the propagation of the upward and downward leaders together with the final jump path. In Fig. 7a is evident a region where the two iso-surfaces of electric field norm equal to 500 kV/m are touching each other. In such a region, the final jump can take place as shown by the result of Fig. 7b.

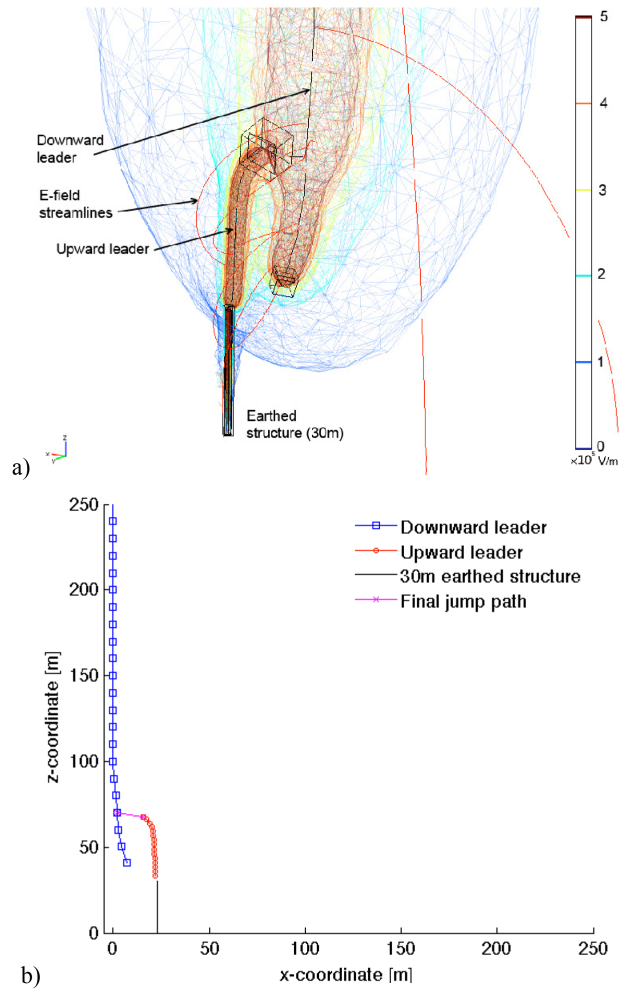

Fig. 7 Final jump estimation concerning the case of a downward leader corresponding to a peak current of 20 kA located at 23 m from the 30 m high earthed structure: a) electric field iso-surfaces and streamlines, b) downward/upward leaders and final jump paths.

3 RESULTS AND COMPARISONS

The procedure to determine the lateral distance for a specific earthed structure and lightning current is the following:

1. definition of the starting point of the downward leader $P_{dl,0}\left(x_0, y_0, z_0\right)=\left(\tilde{x}, 0, 2000\right)$ where subscript '0' indicates the initial step of the leader propagation and $\tilde{x}$ the distance between the downward leader projection on the *xy* plane and the earthed structure supposed located in the center of Ω (in the first simulation $\tilde{x}=0$, namely the downward leader descends in correspondence of the earthed structure);
2. leaders progression simulation in order to determine whether one of the two following conditions is verified: i) the two leaders are touching each other, ii) a final jump takes place;
3. shift of the starting point of the downward leader by increasing the $\tilde{x}$ coordinate, and iterative repetition of points 1 and 2.

When condition 2 is not verified for the first time during the process, the corresponding $\tilde{x}$ defines the lateral distance.

Fig. 8 shows an example of the lateral distance assessment concerning the case of a 20 kA current for $\tilde{x}$ =23 m, 36 m, 37,5 m and 39.5 m.

In order to compare the results obtained with the proposed LPM-FEM model with those of [10-12], we have made reference to the case of a 30 m structure for which we have determined the lateral distances in correspondence of the lightning currents of 10, 20, 50 and 100 kA. Fig. 9 shows such a comparison. As it can be seen, in the low current region the LPM-FEM essentially provides the same results of the original version of the LPM, whilst for currents larger than 50 kA the results of the LPM-FEM tends to result into lower lateral distances. The results obtained with the LPM-FEM seems to be in agreement with other lateral distance expressions provided in the literature that predicts a non-linear dependency of the lateral distance with the lightning current.

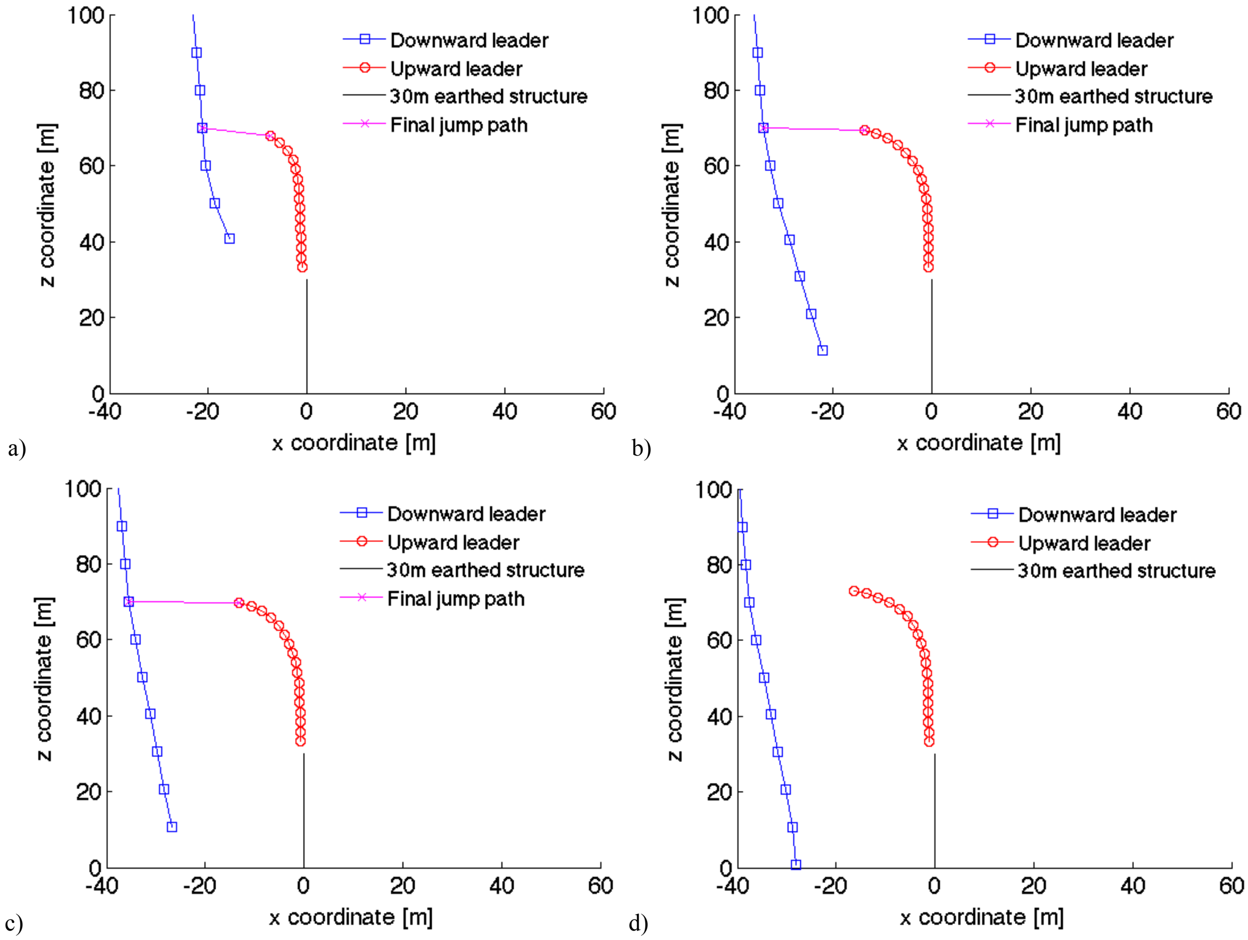

Fig. 8 Lateral distance estimation for the case of a 30 m high earthed structure and 20 kA lightning current: a) $\tilde{x}$ =23 m, b) $\tilde{x}$ =36 m, c) $\tilde{x}$ = 37.5 m, d) $\tilde{x}$ =39.5 m.

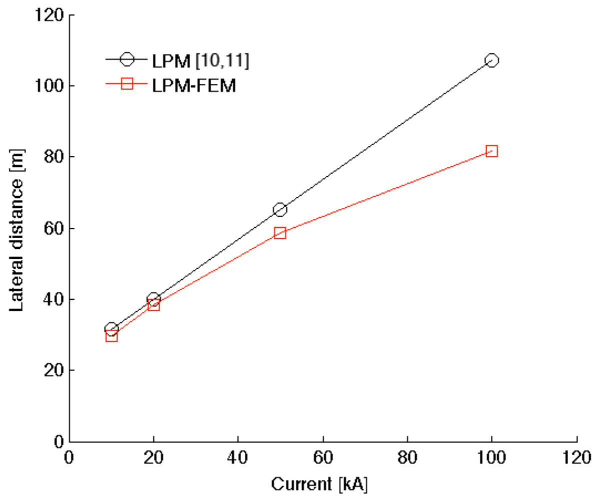

Fig. 9 Comparison between lateral distances of [10-12] with the ones obtained with the LPM-FEM, 30 m high earthed structure.

4 CONCLUSIONS

The paper has proposed the solution of the leader progression model by means of the finite element method. Compared with the charge simulation method, the one here proposed allows to straightforward take into account the boundary conditions of the problems. This avoids the use of virtual charges, needed in [10-12] to find the solution of the electrostatic field distribution, resulting into the following advantages: i) the electric scalar potential in correspondence of the earthed structure is inherently null as it is a boundary condition of the problem, ii) the inception of the upward leader can be evaluated in correspondence of any point of the earthed structure and even multiple upward leaders can be taken into account.

In view of the numerical solution of the electrostatic problem provided by the FEM, it also presents the following further advantages:

- representation of any charge distribution for both upward and downward leaders;
- implementation of different final jump criteria;
- implementation of different inception models;
- representation on any 3D earthed structure (of interest for asymmetrical structure configurations).

Future works will be devoted to the possible numerical evaluation of the streamer zone extension (in front of the leader tips) by means of a representation the non-linear properties of the medium.

5 ACKNOLEGMENTS

The authors wish to thank CESI s.p.a., for providing the access to the original LPM code and the share of the LPM contents.

Thanks are also due to D. Sbrega for his help in performing the calculations.

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Annexe 4

Simulations graphiques et modèles

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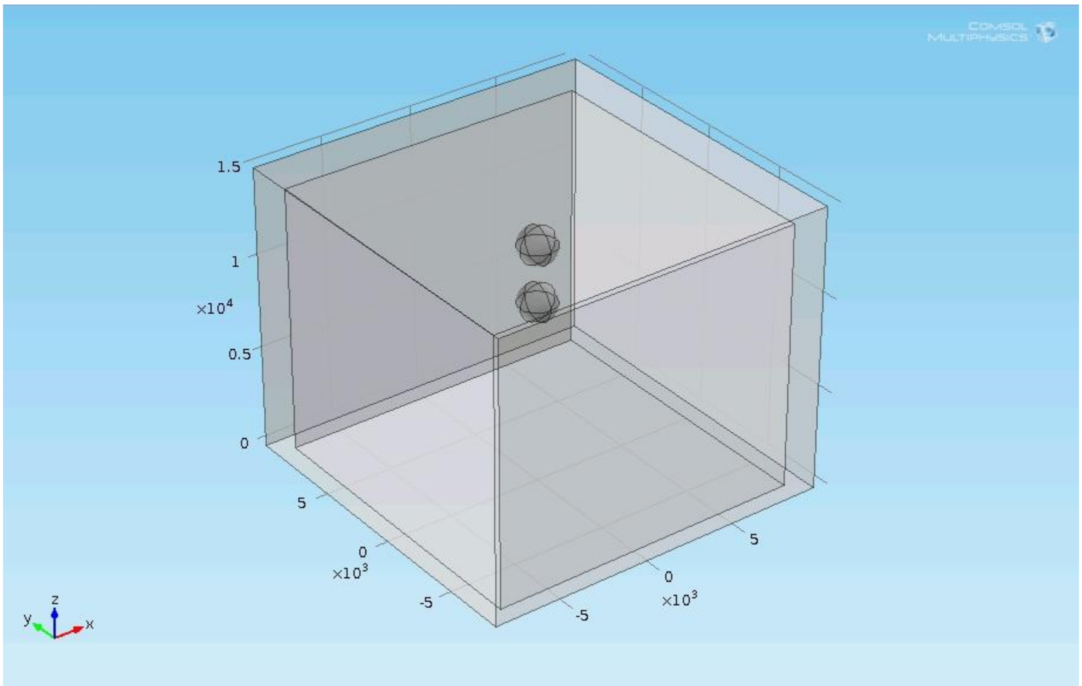


Figure 1 Modèle sans montagne sans tour

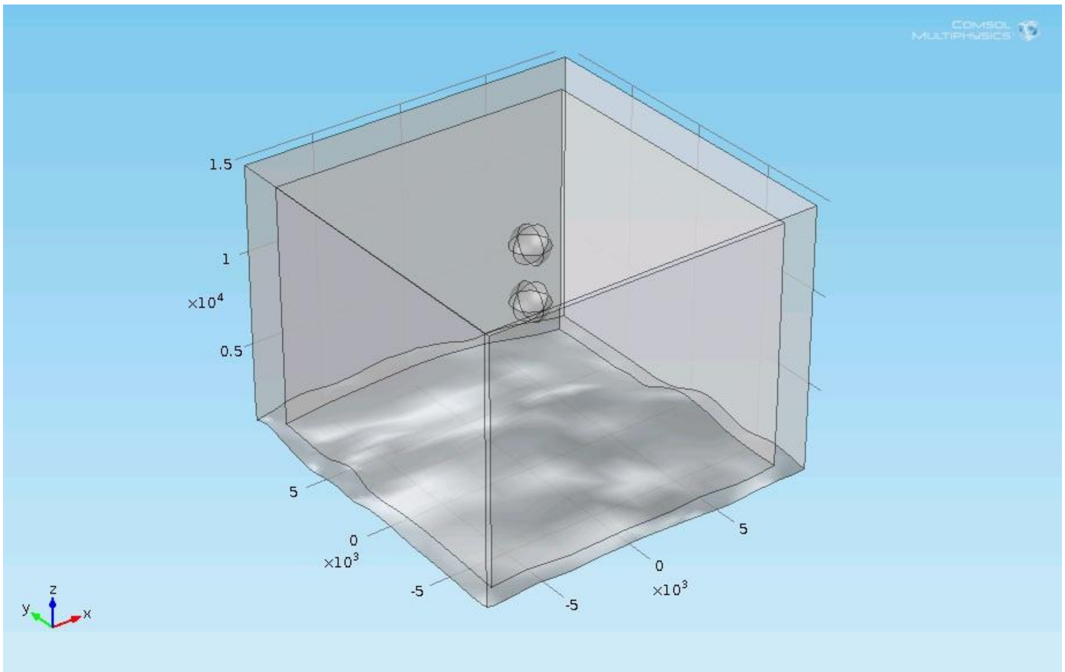


Figure 2 Modèle avec montagne sans tour

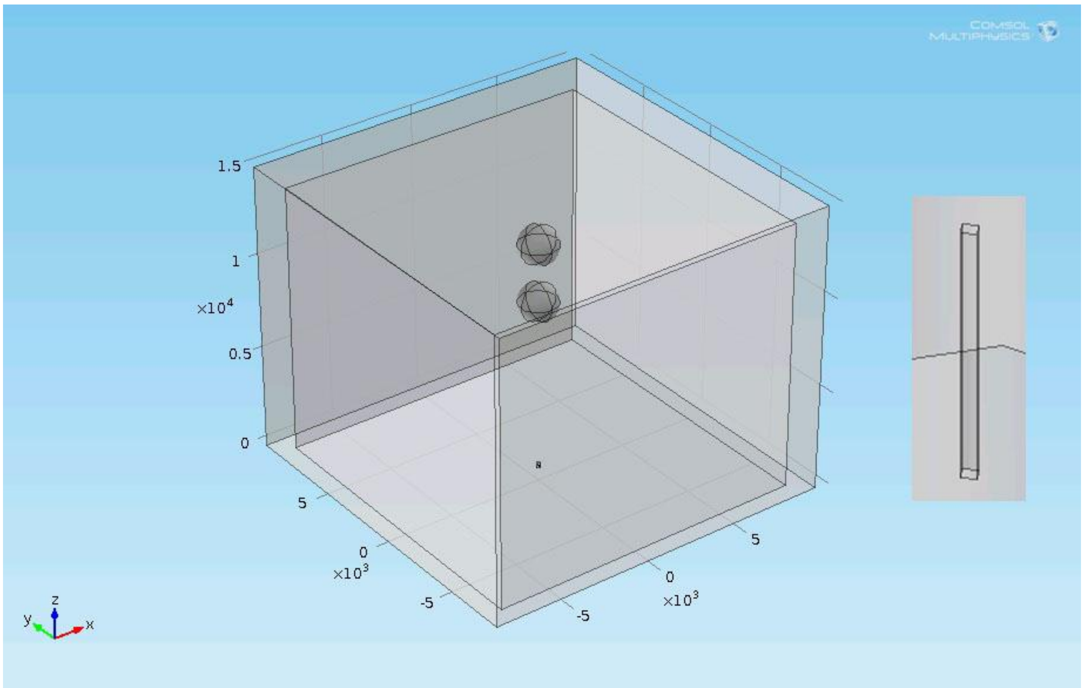


Figure 3 Modèle sans montagne avec tour plate

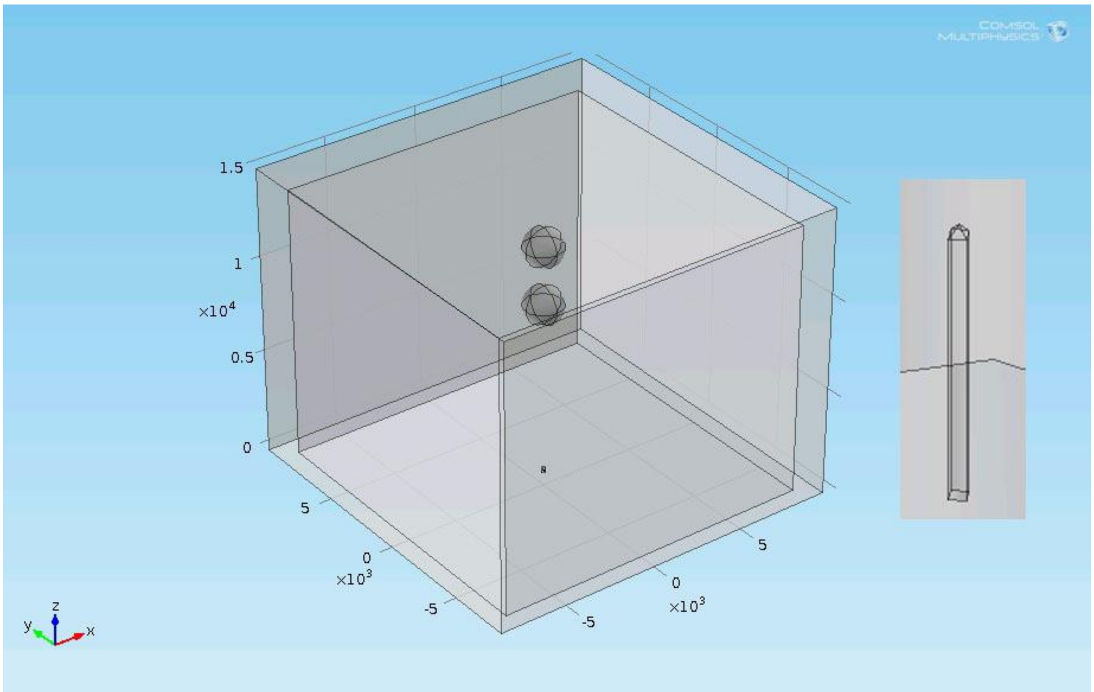


Figure 4 Modèle sans montagne avec tour arrondie

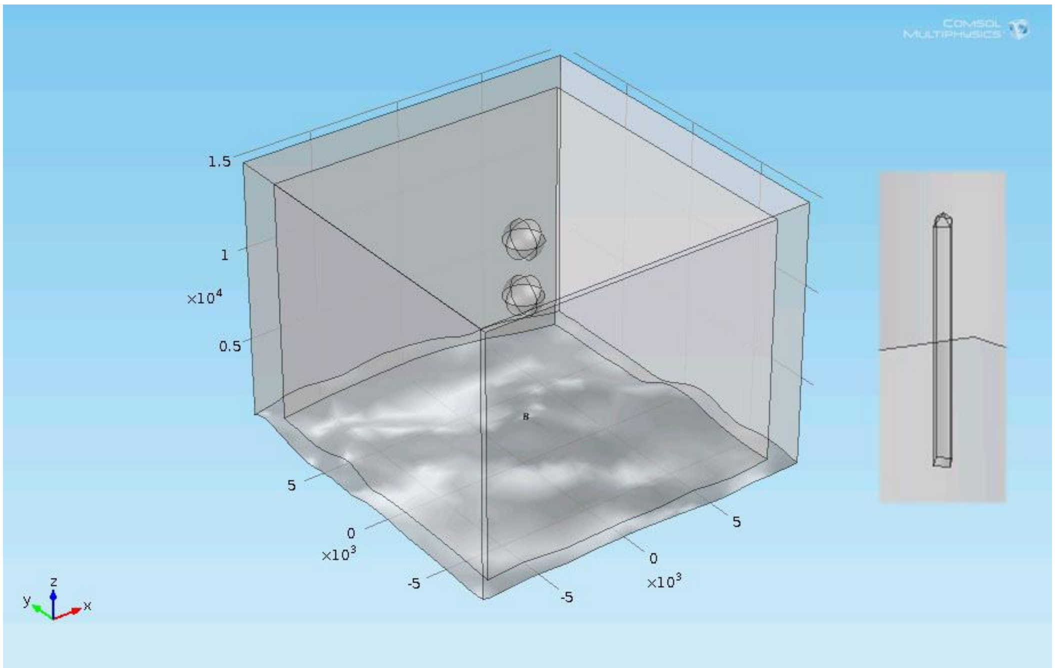


Figure 5 Modèle avec montagne avec tour arrondie

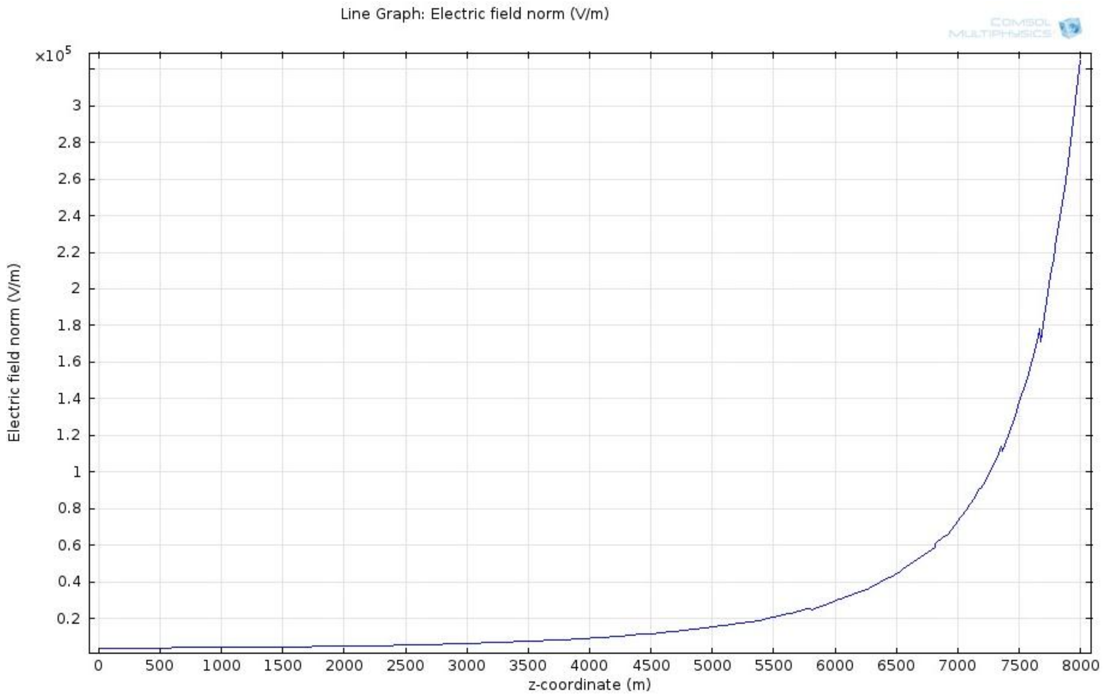


Figure 6 Graphique sans montagne sans tour nuage à 8km

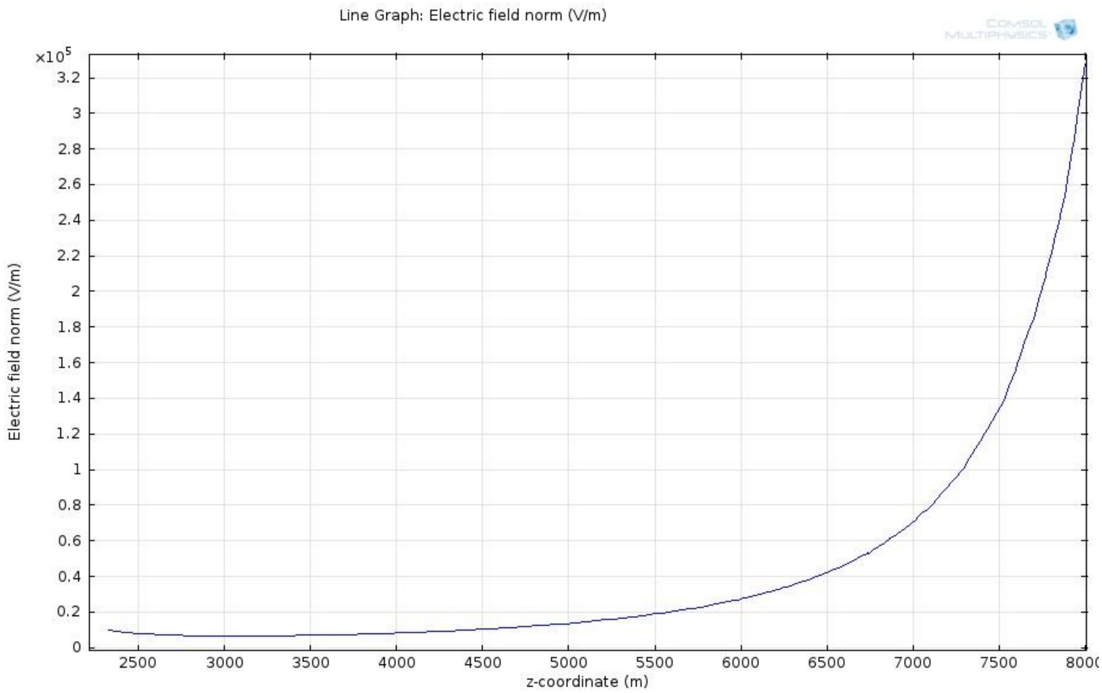


Figure 7 Graphique avec montagne sans tour nuage à 8km

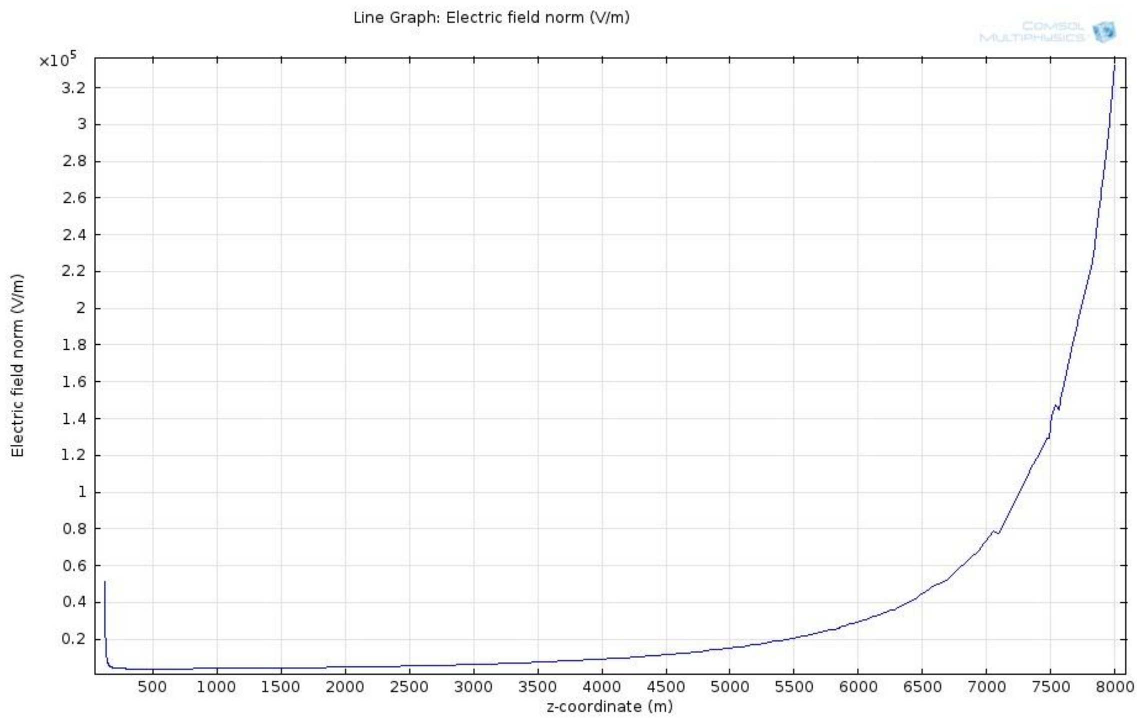


Figure 8 Graphique sans montagne avec tour plate nuage à 8km

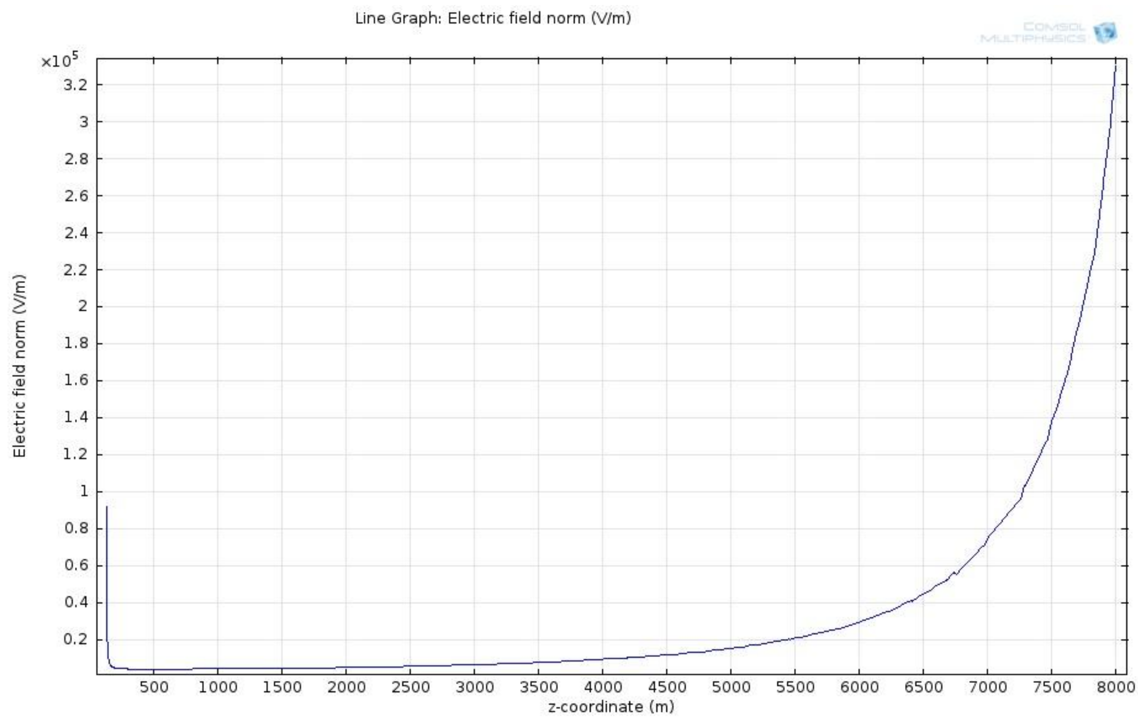


Figure 9 Graphique sans montagne avec tour arrondie nuage à 8km

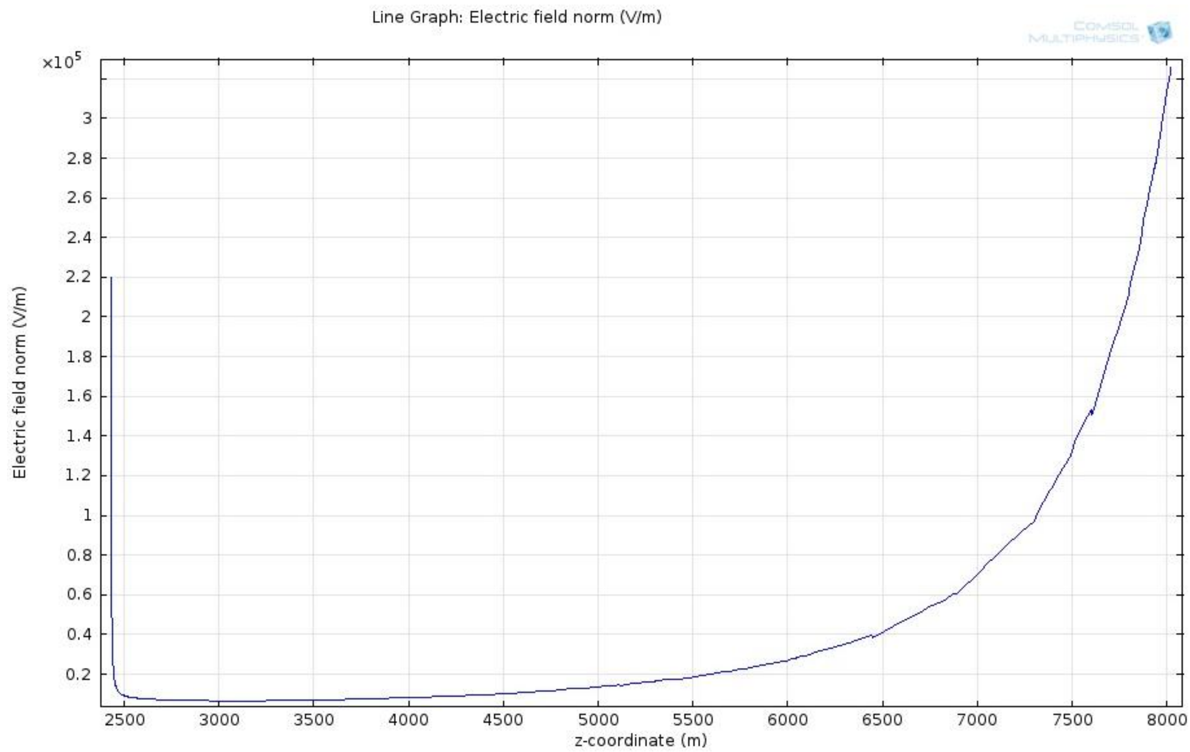


Figure 10 Graphique avec montagne avec tour arrondie nuage à 8km

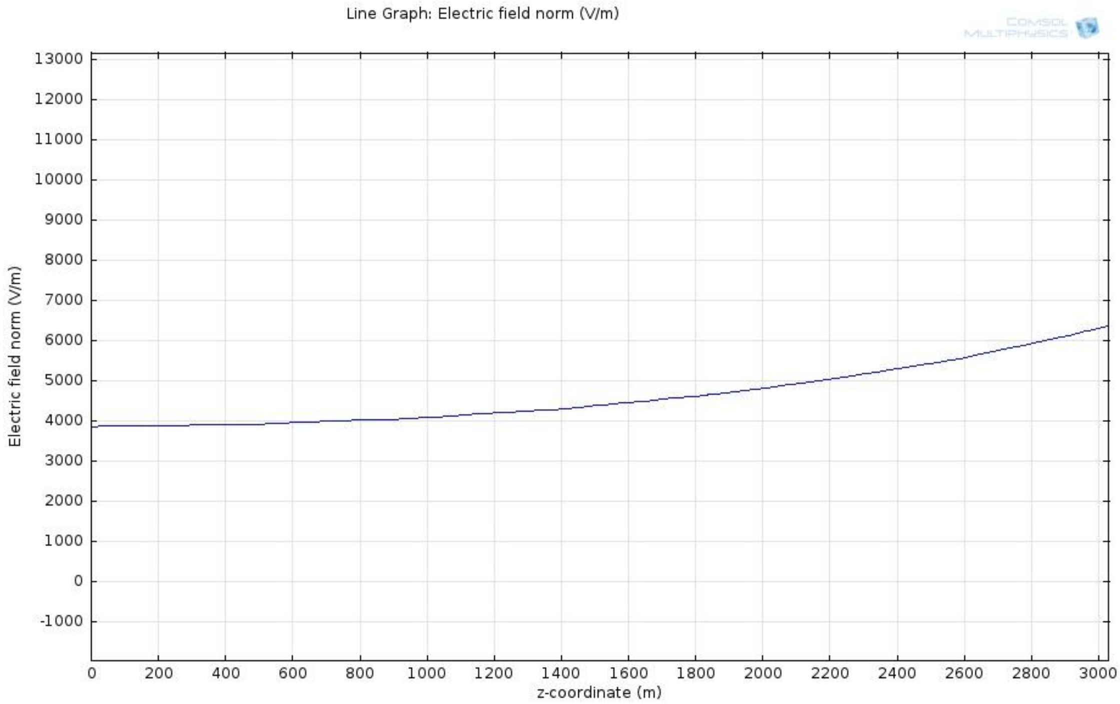


Figure 11 Graphique sans montagne sans tour nuage à 8km zoom

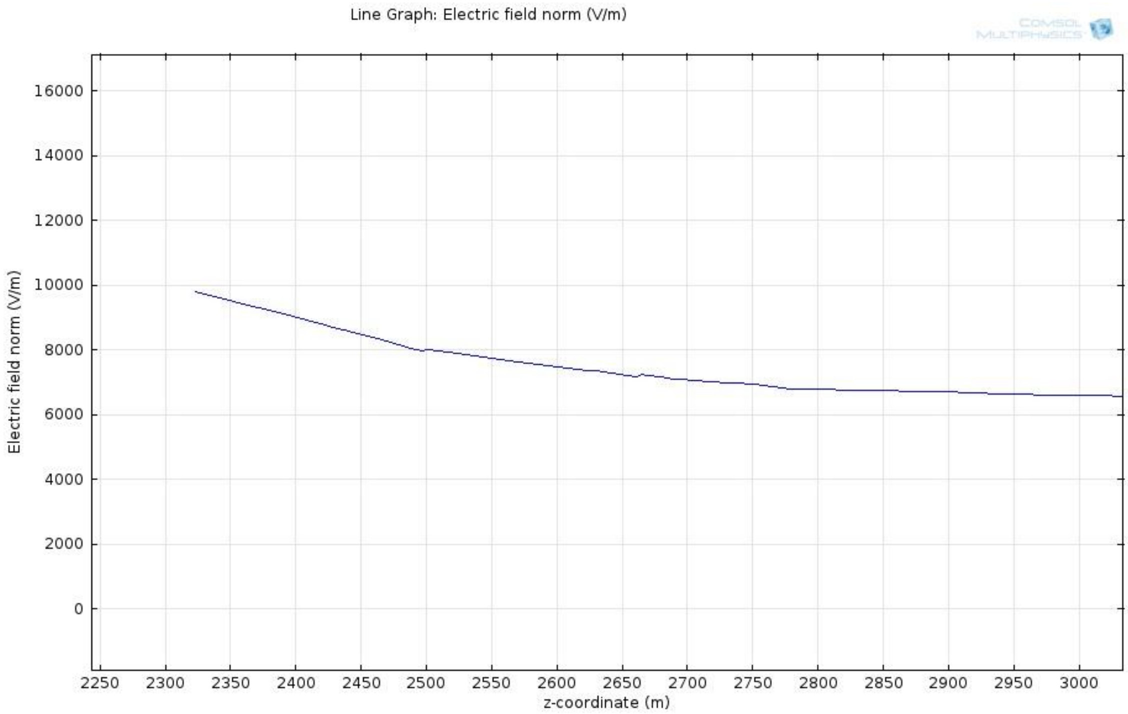


Figure 12 Graphique avec montagne sans tour nuage à 8km zoom

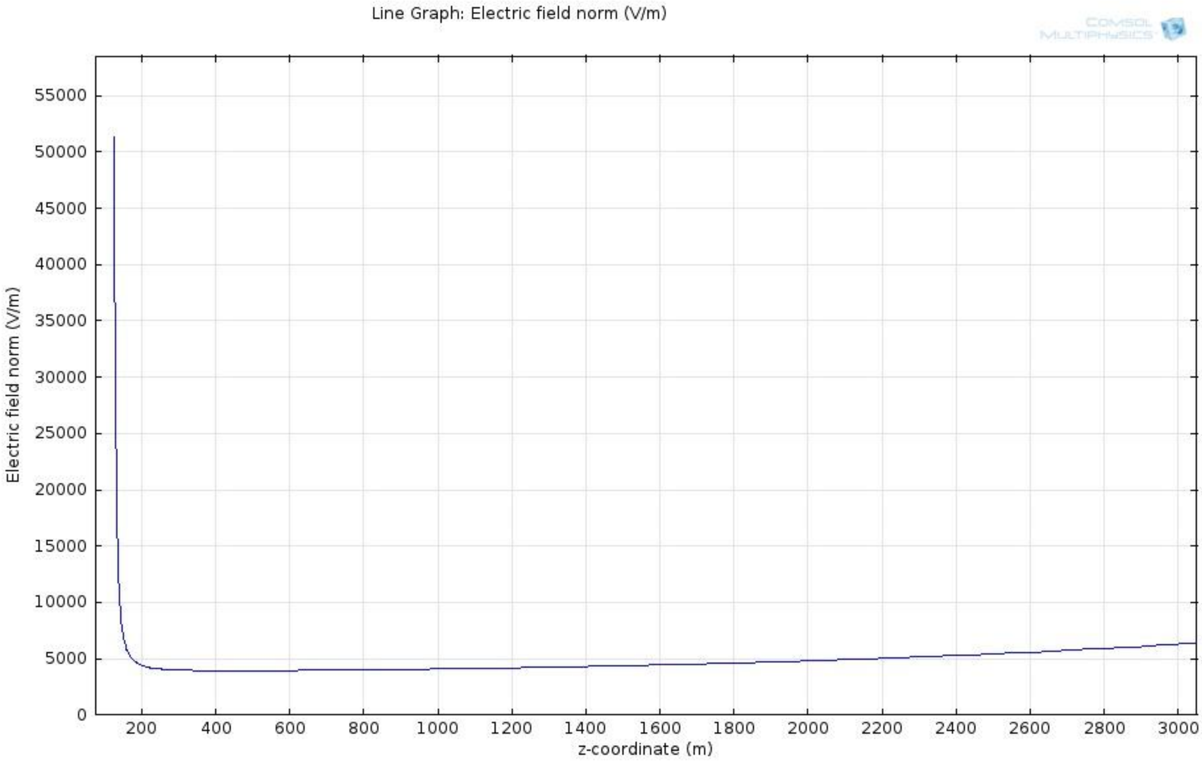


Figure 13 Graphique sans montagne avec tour plate nuage à 8km zoom

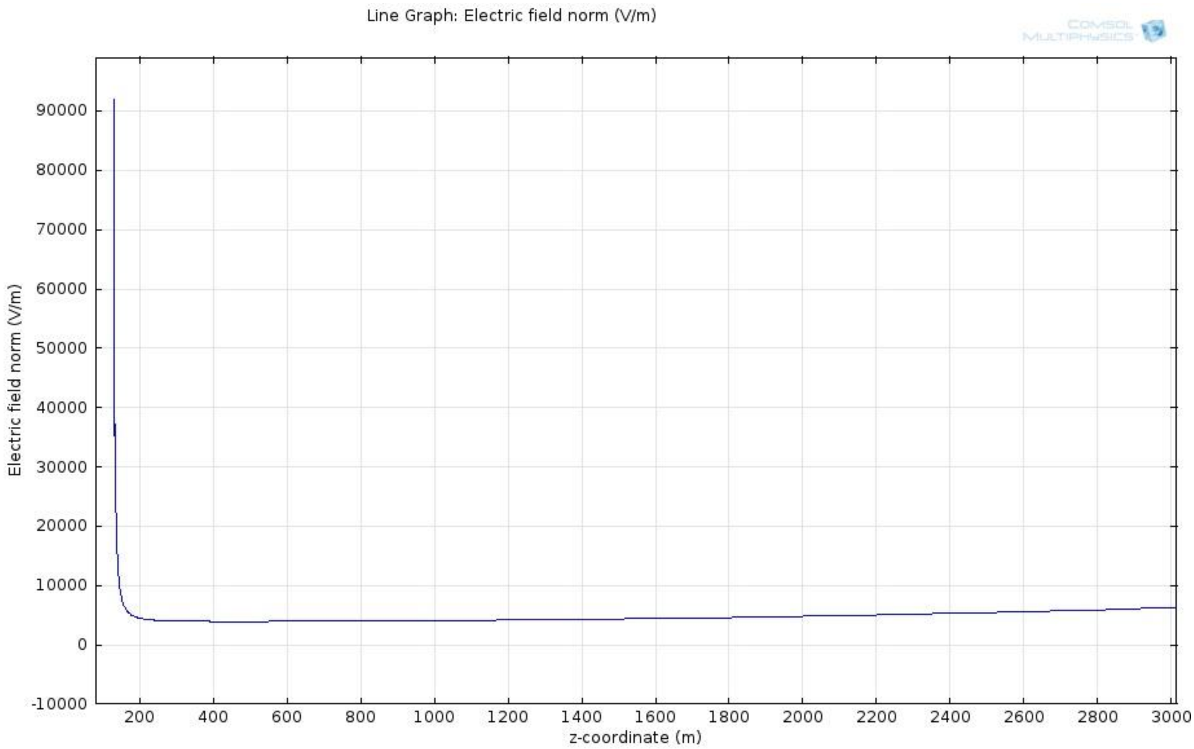


Figure 14 Graphique sans montagne avec tour arrondie nuage à 8km zoom

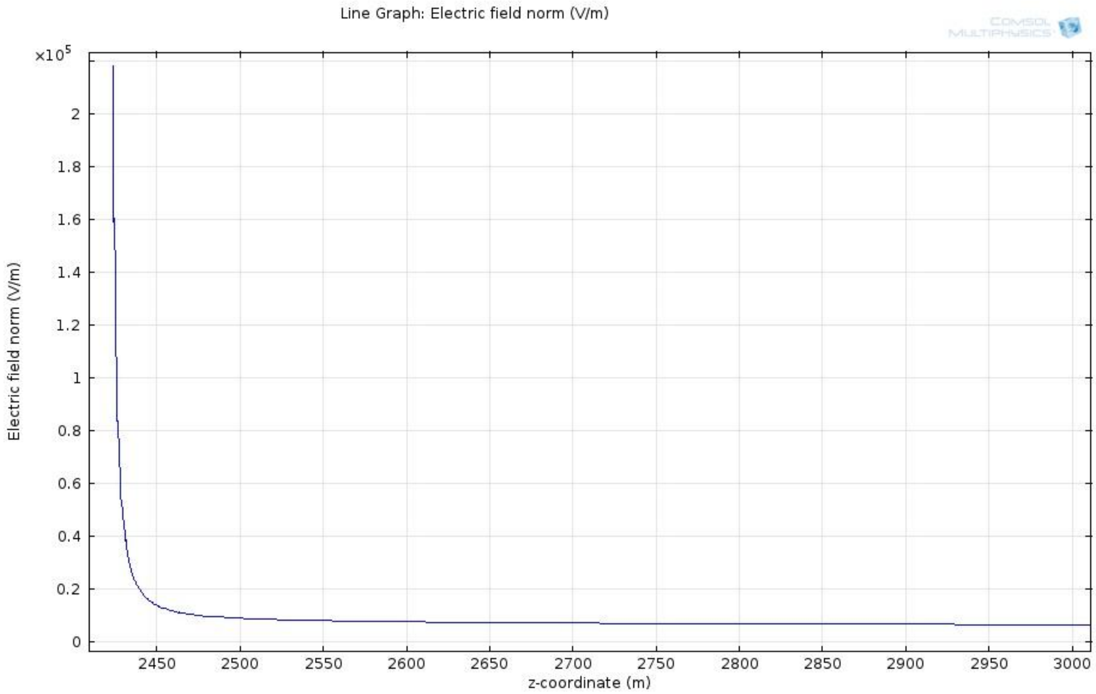
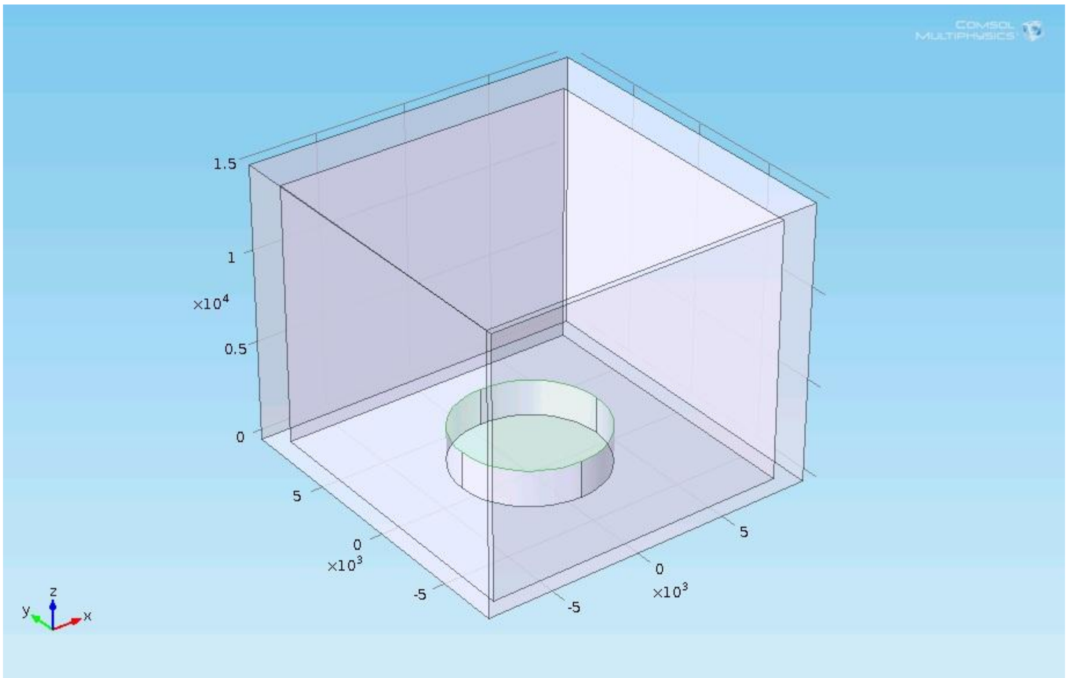


Figure 15 Graphique avec montagne avec tour arrondie nuage à 8km zoom



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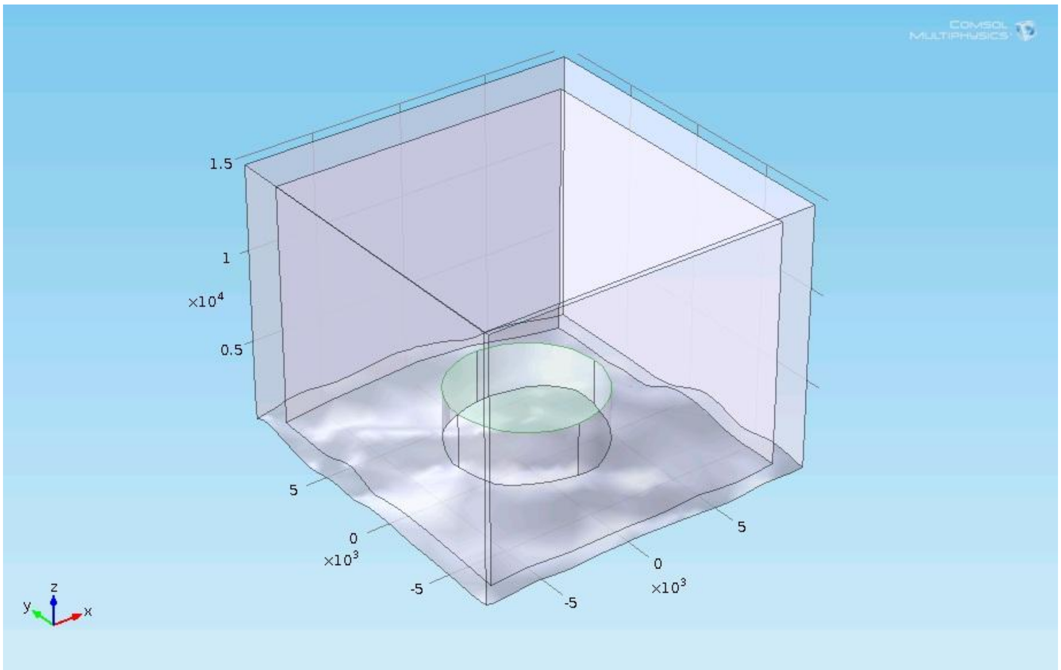

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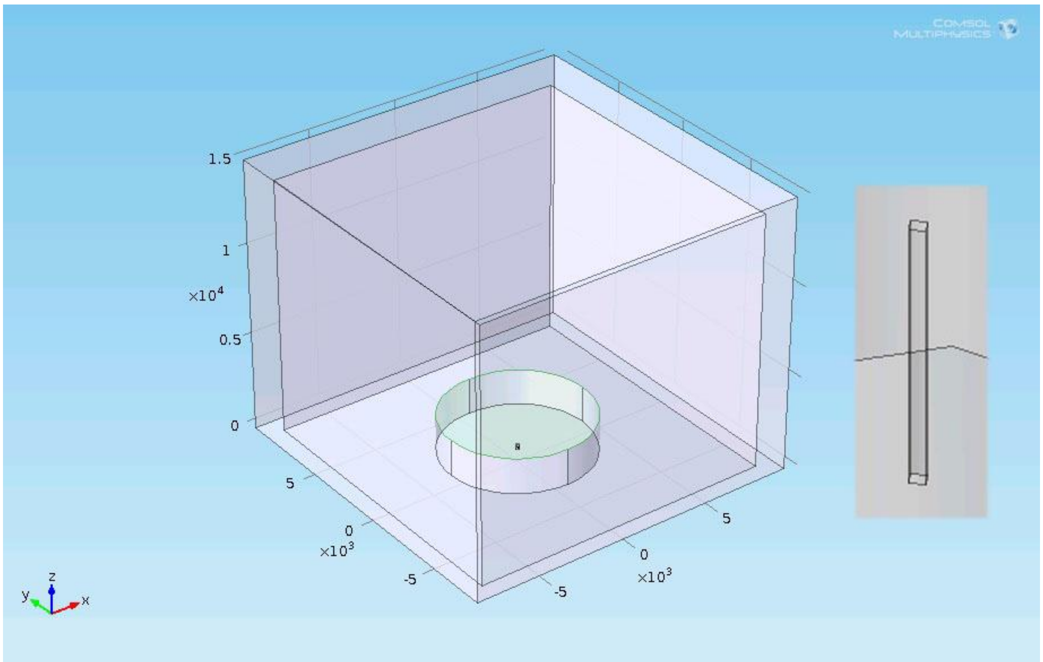

Figure 3 Modèle sans montagne avec tour plate

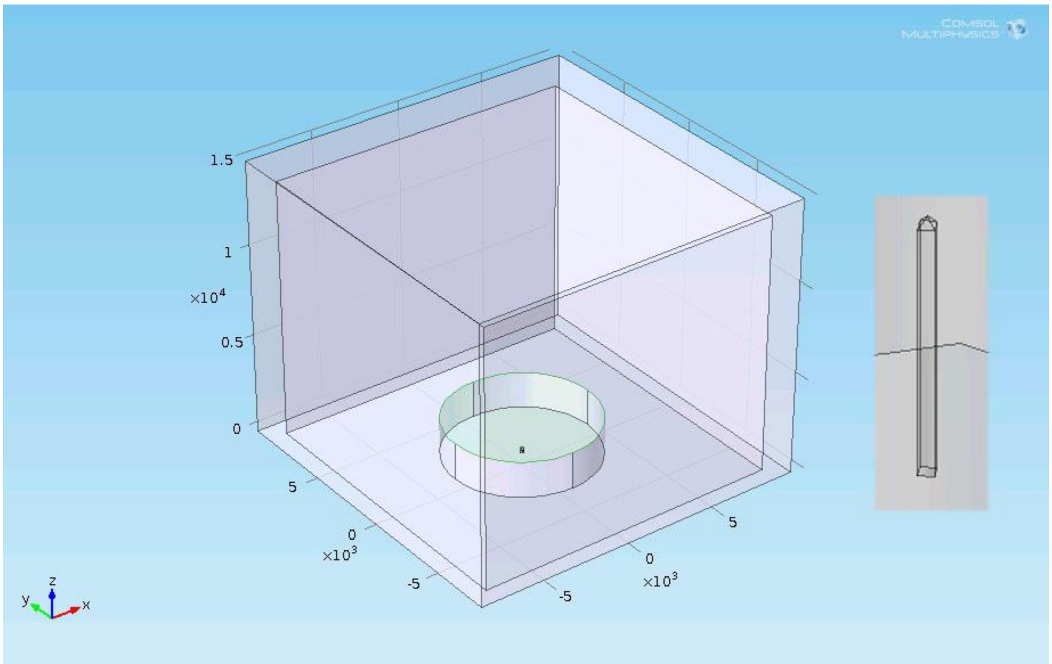

Figure 4 Modèle sans montagne avec tour arrondie

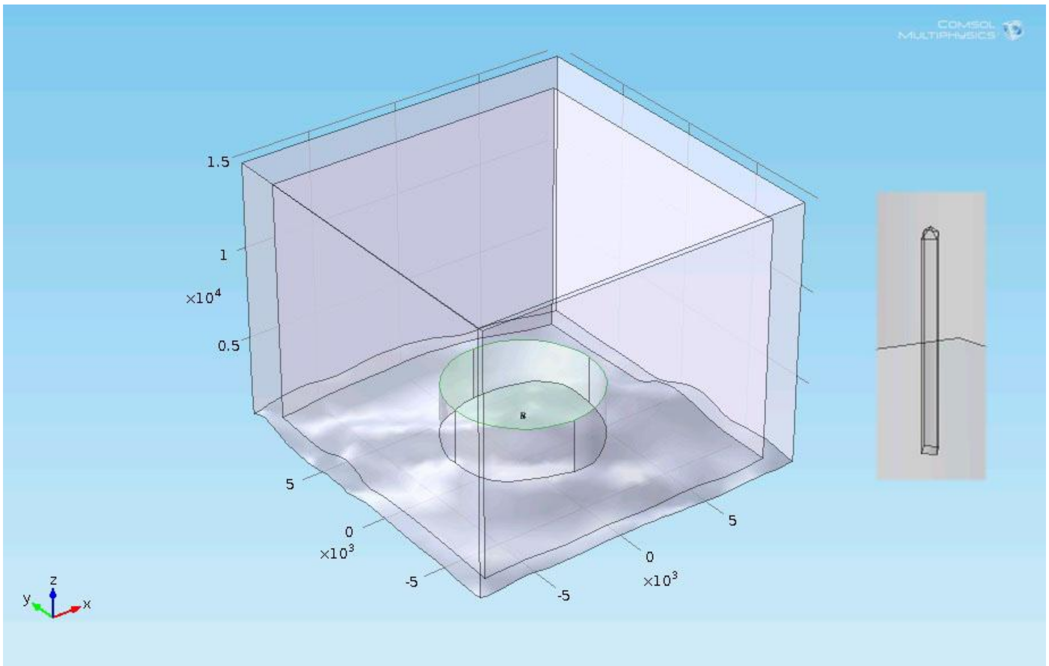

Figure 5 Modèle avec montagne avec tour arrondie

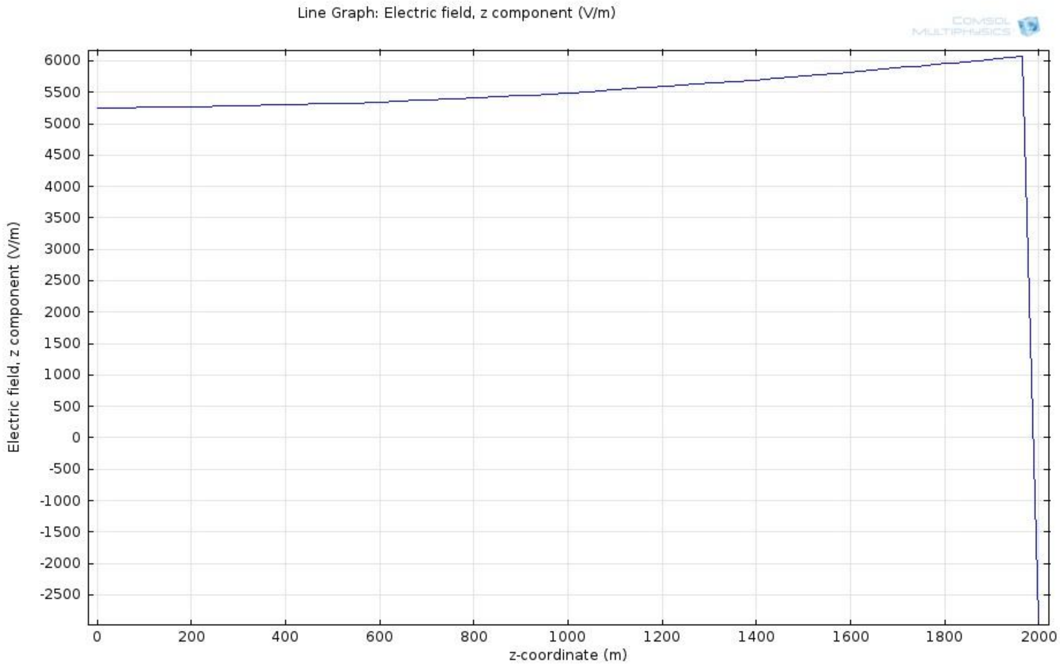

Figure 6 Graphique sans montagne sans tour disque à 2km du sol

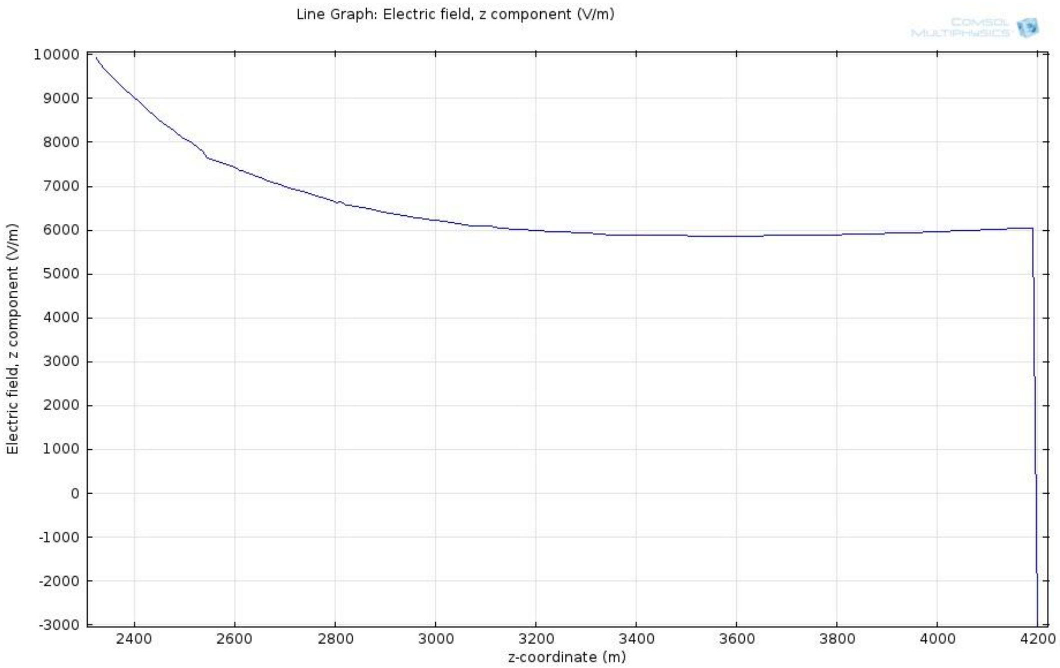

Figure 7 Graphique avec montagne sans tour disque à 2km du sol

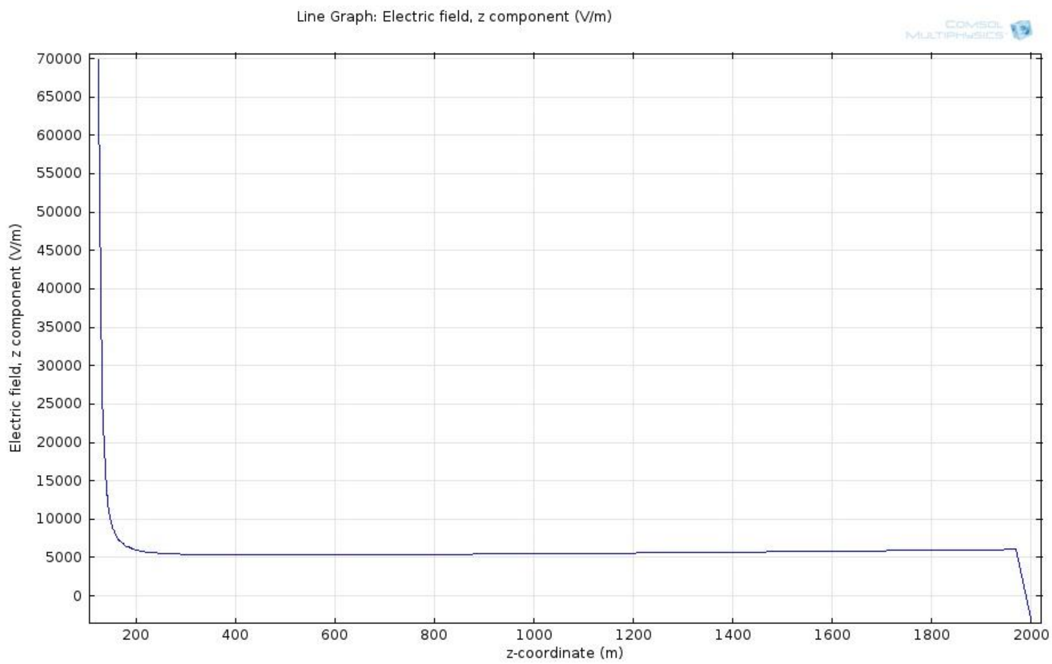

Figure 8 Graphique sans montagne avec tour plate disque à 2km du sol

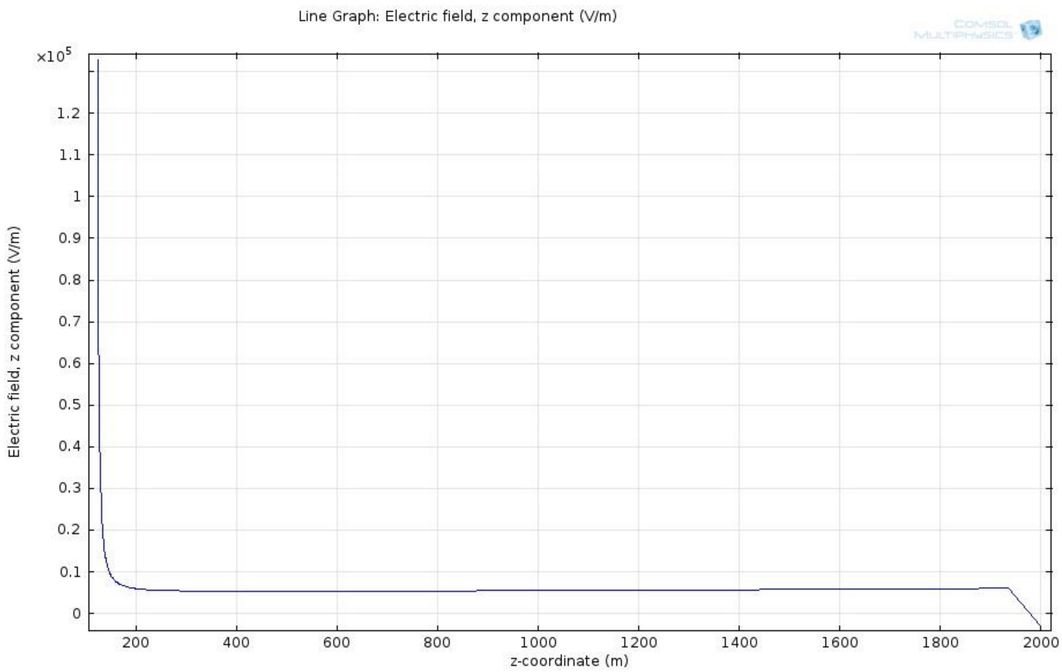

Figure 9 Graphique sans montagne avec tour arrondie disque à 2km du sol

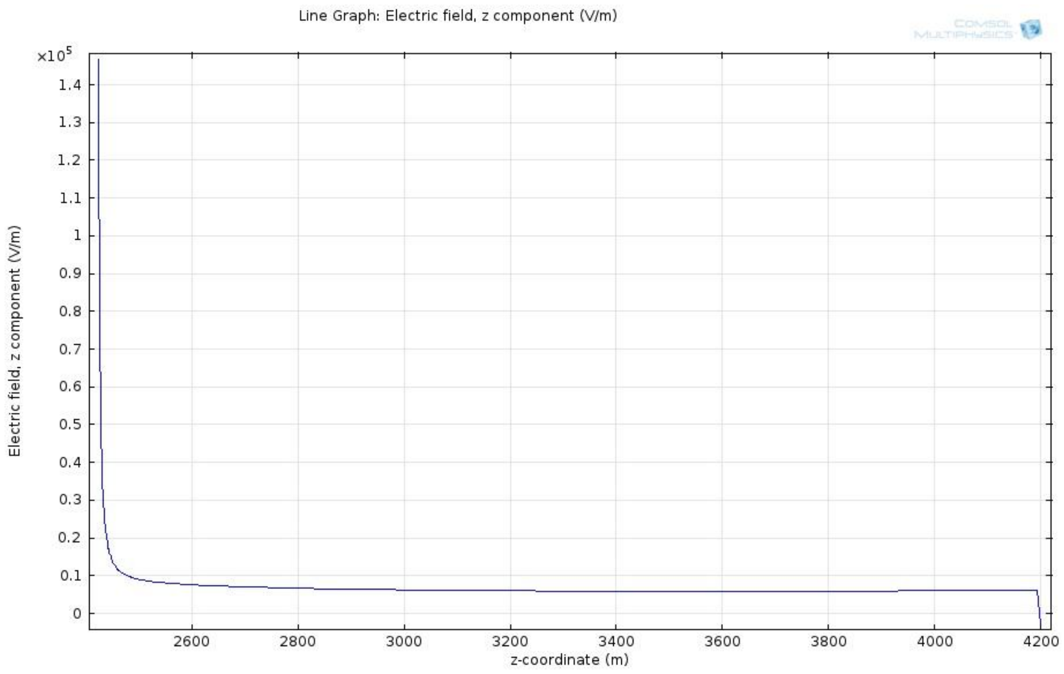

Figure 10 Graphique avec montagne avec tour arrondie disque à 2km du sol

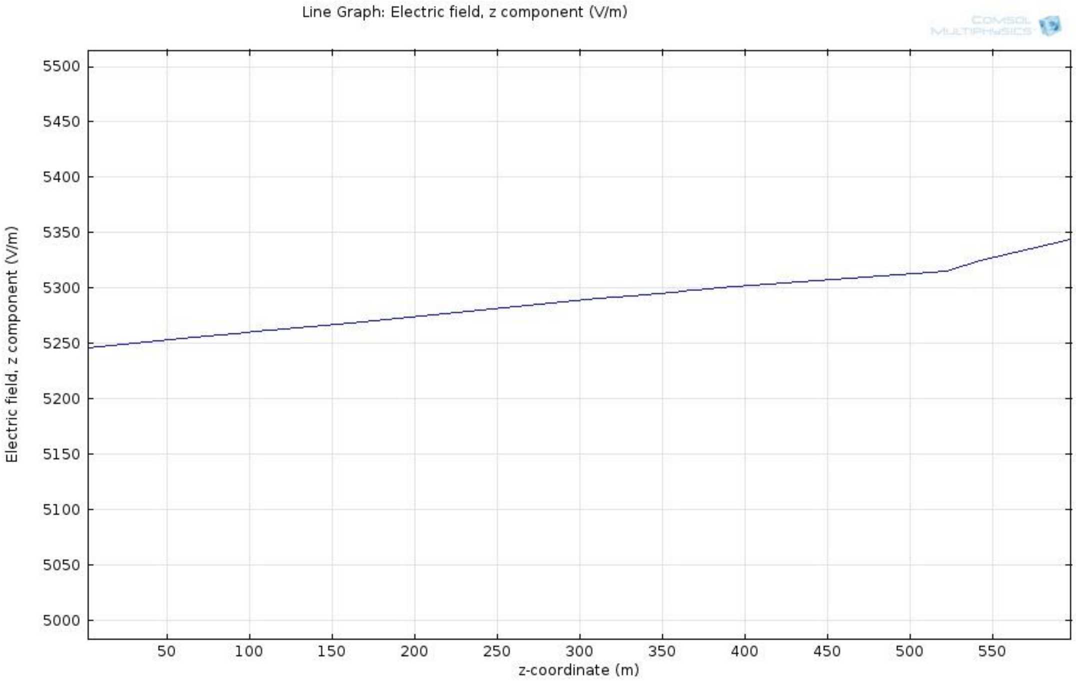

Figure 11 Graphique sans montagne sans tour disque à 2km du sol zoom

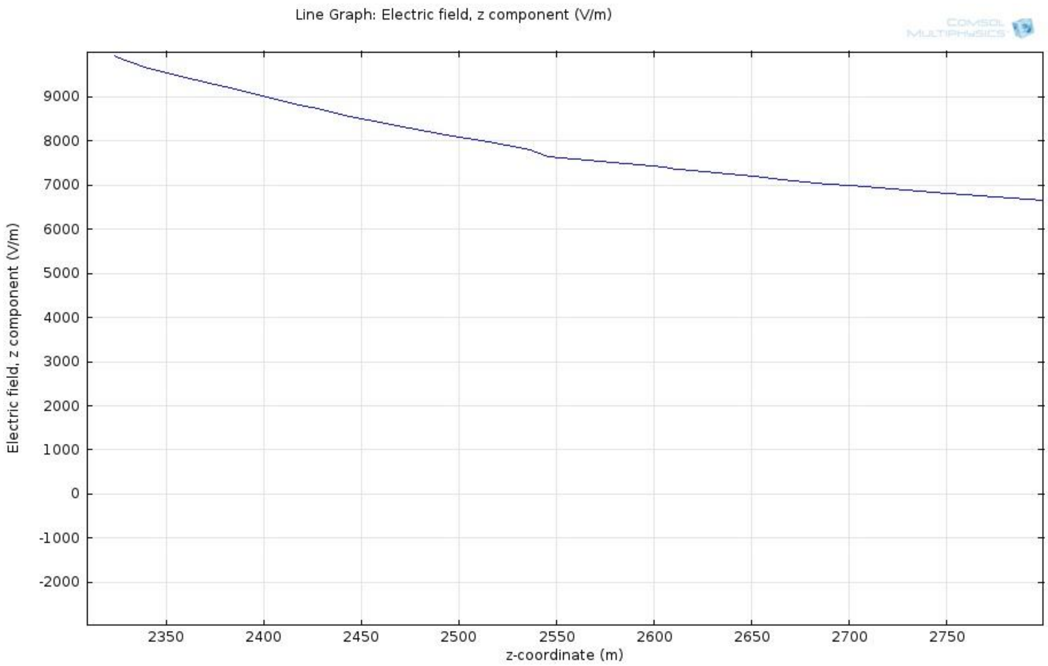

Figure 12 Graphique avec montagne sans tour disque à 2km du sol zoom

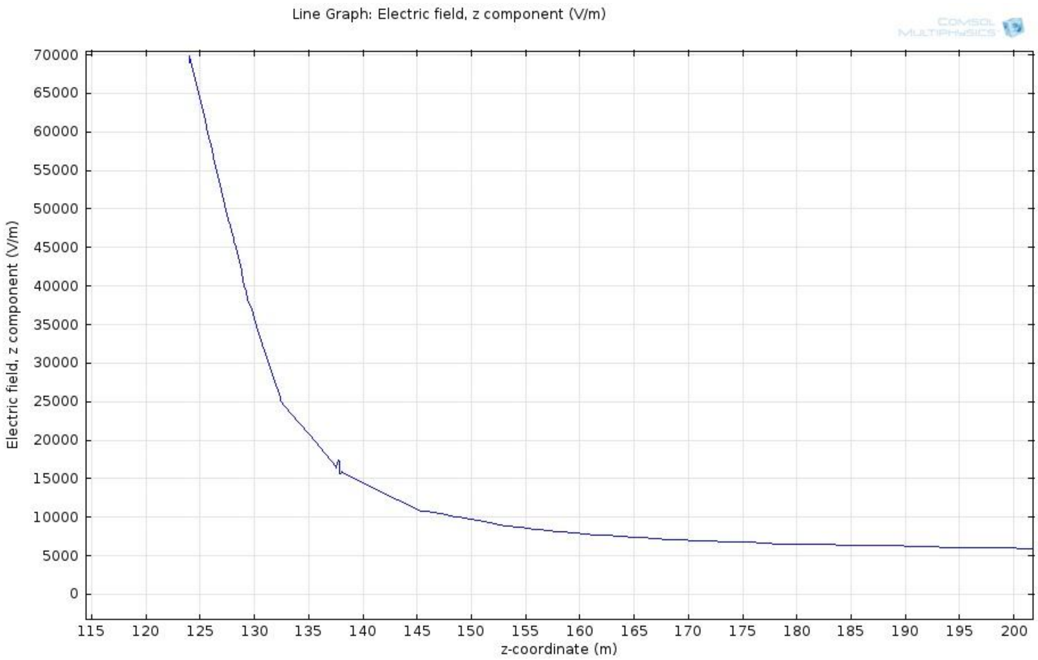

Figure 13 Graphique sans montagne avec tour plate disque à 2km du sol zoom

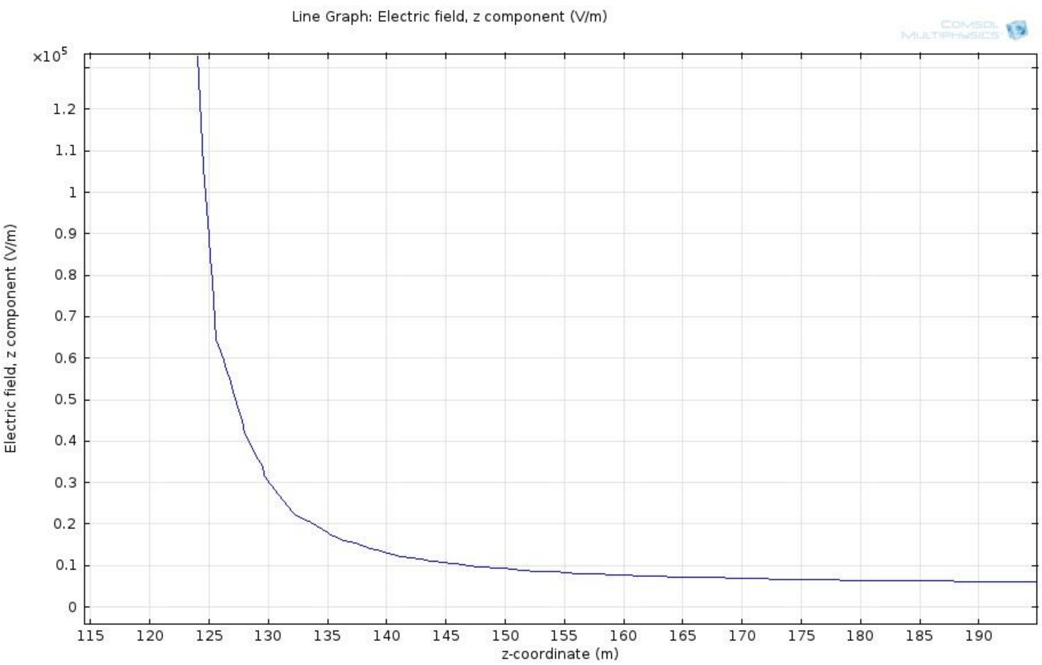

Figure 14 Graphique sans montagne avec tour arrondie disque à 2km du sol zoom

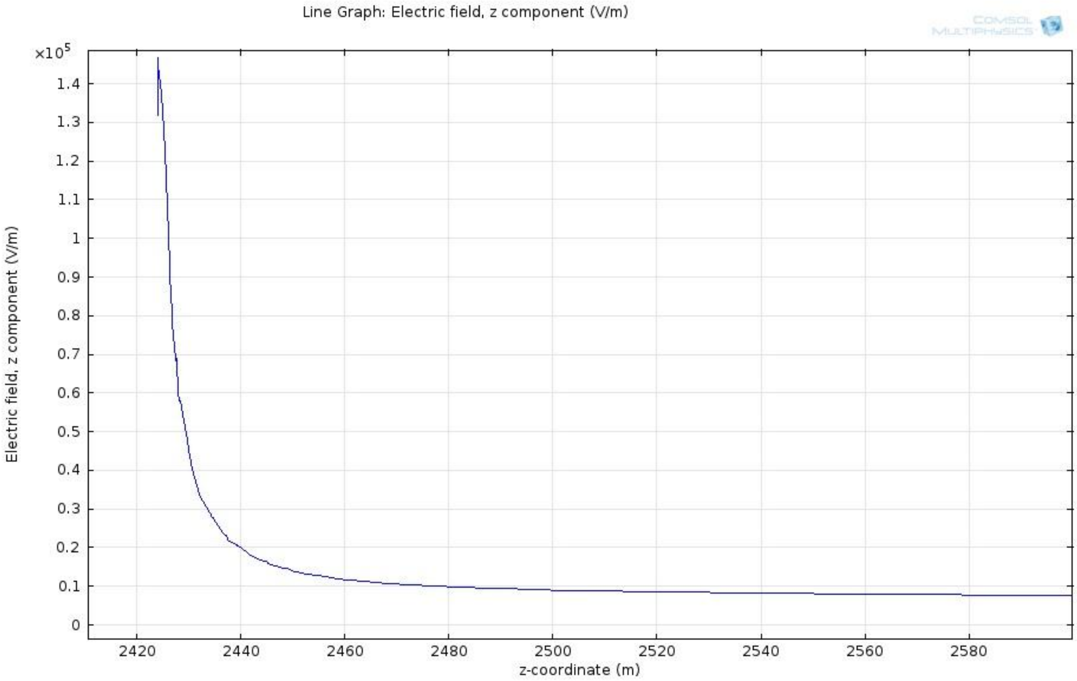

Figure 15 Graphique avec montagne avec tour arrondie disque à 2km du sol zoom

Annexe 5

Simulations sous la coupole

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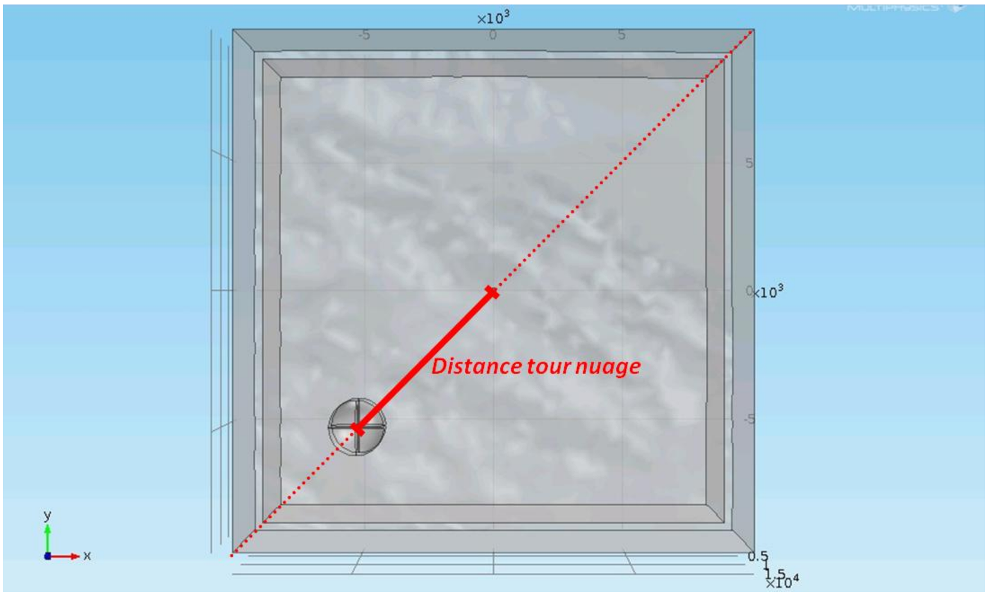


Figure 1 Modèle simulation ; nuage 8km d'altitude, charge 36.3C, distance variable

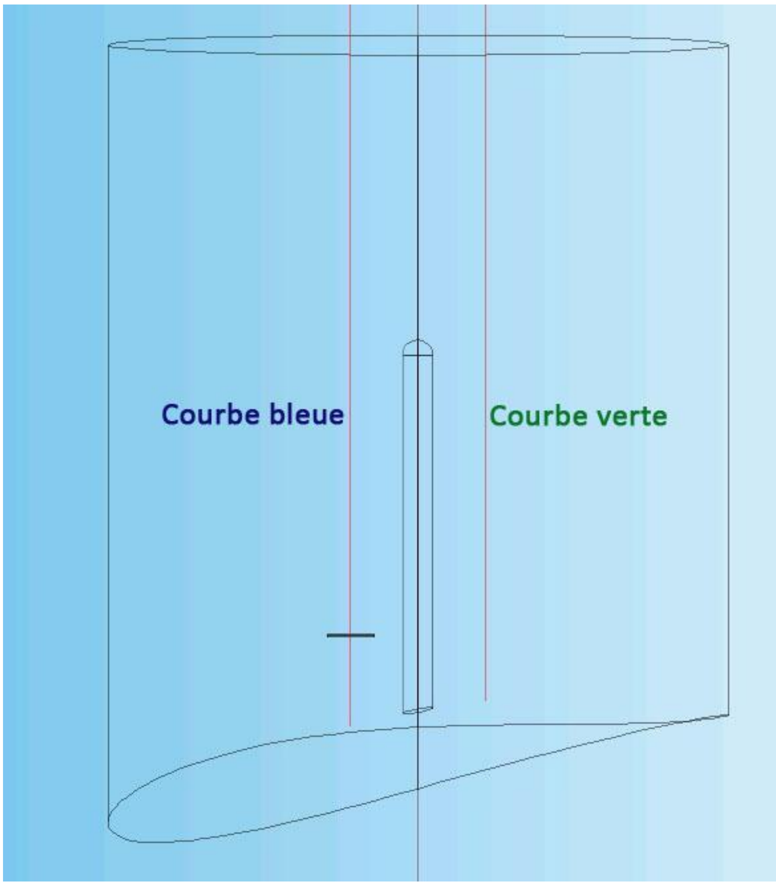


Figure 2 Lignes de mesures des courbes

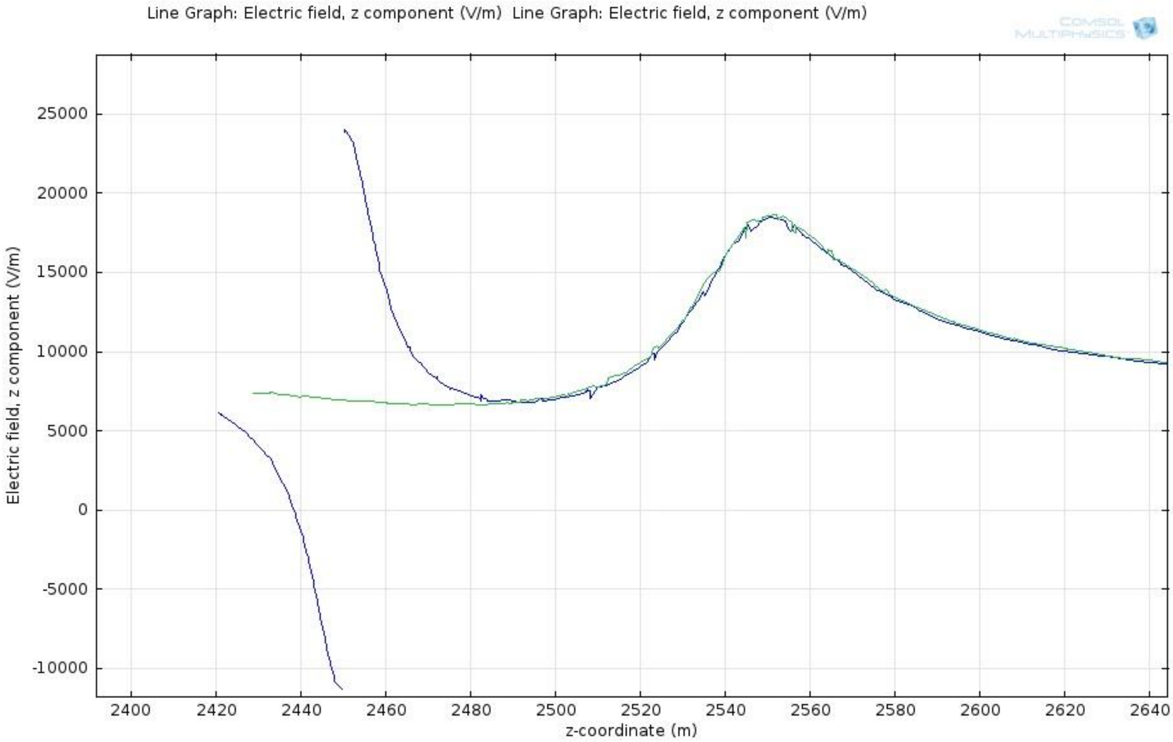


Figure 3 Nuage aligné dans l'axe de la tour

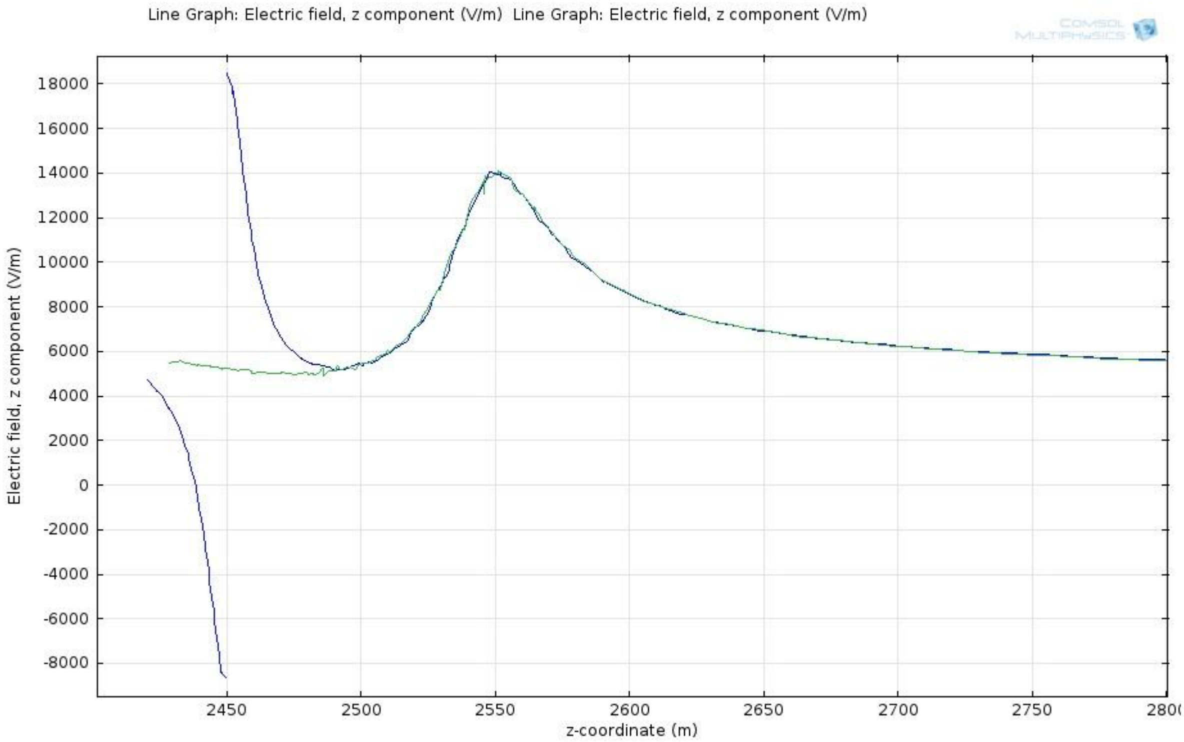


Figure 4 Nuage à 2km de la tour

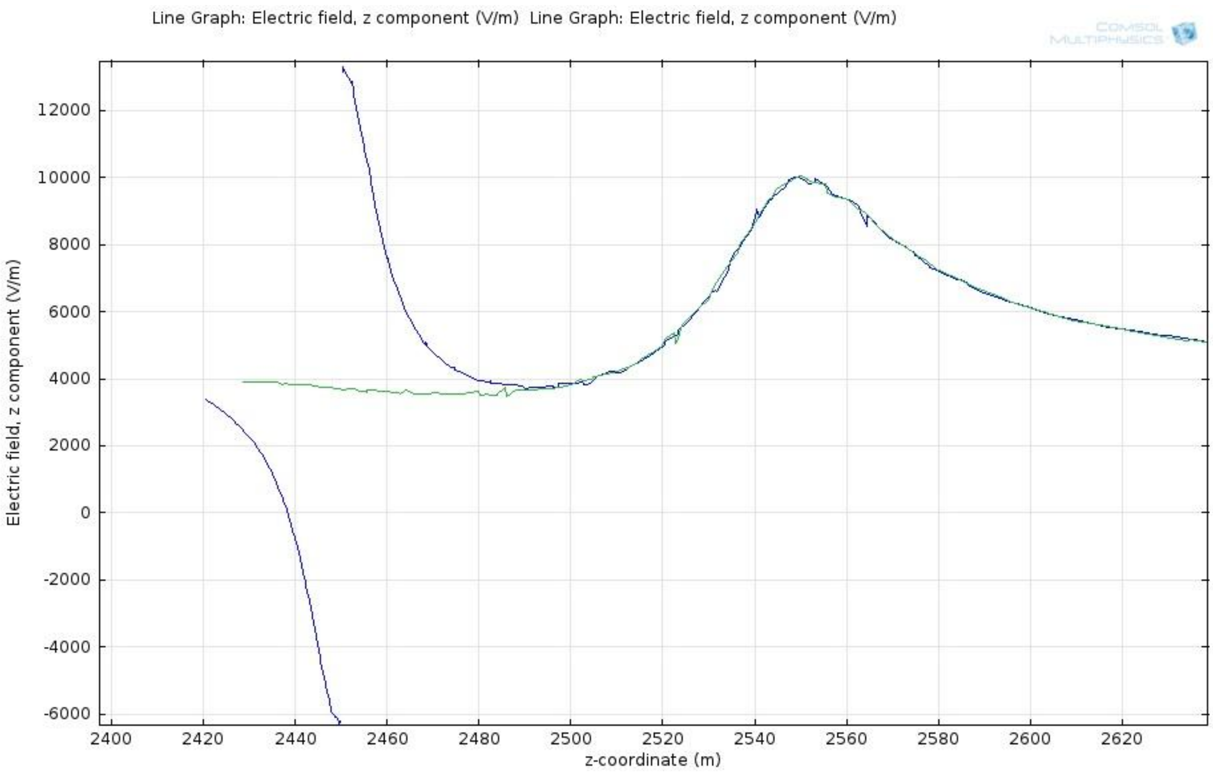


Figure 5 Nuage à 3km de la tour

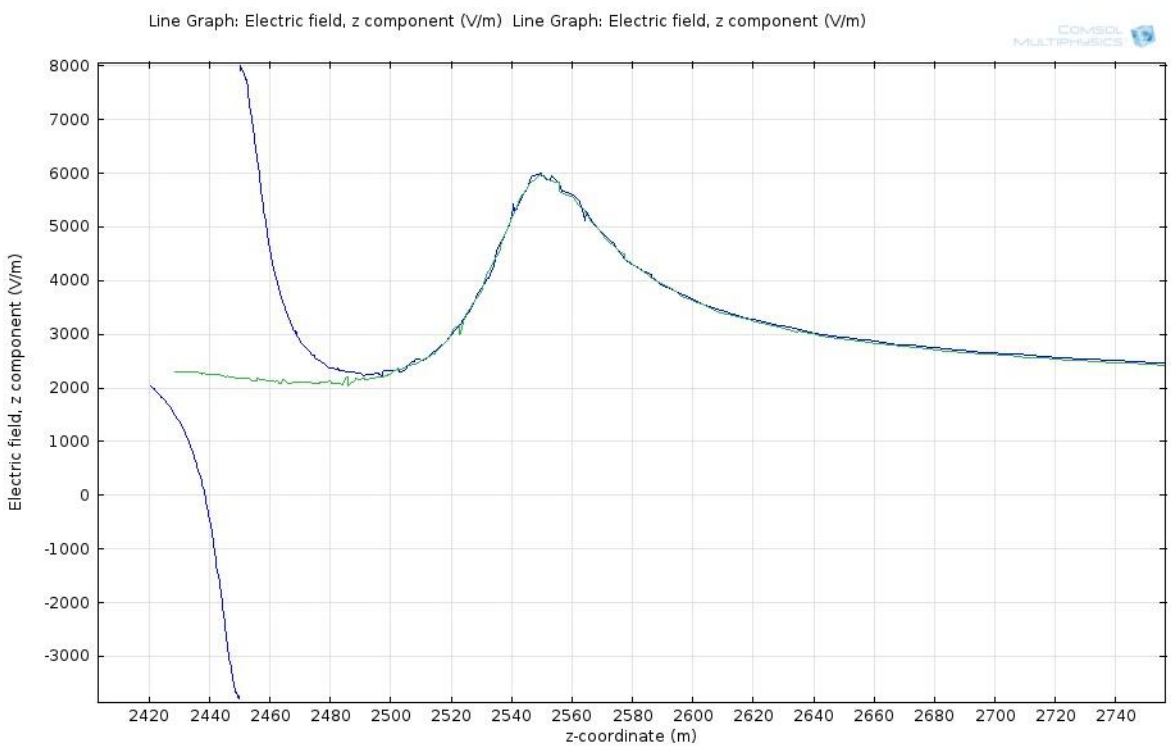


Figure 6 Nuage à 4km de la tour

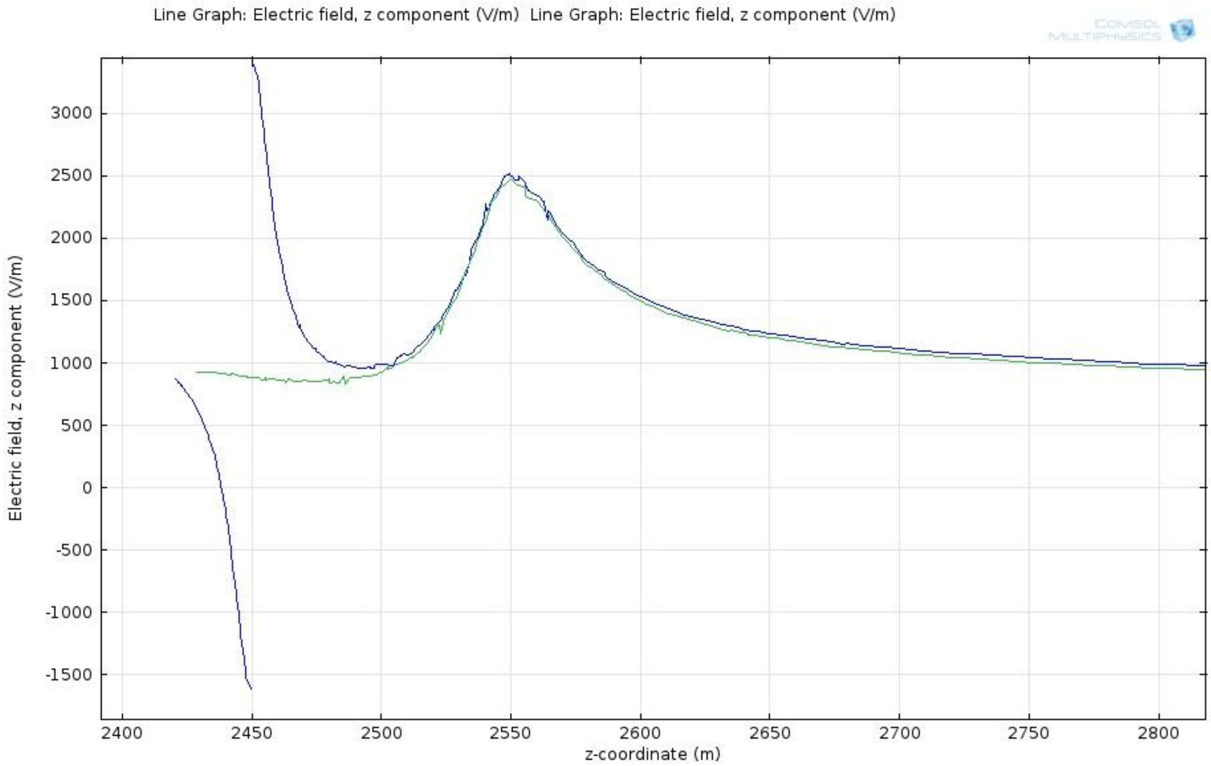


Figure 7 Nuage à 5km de la tour

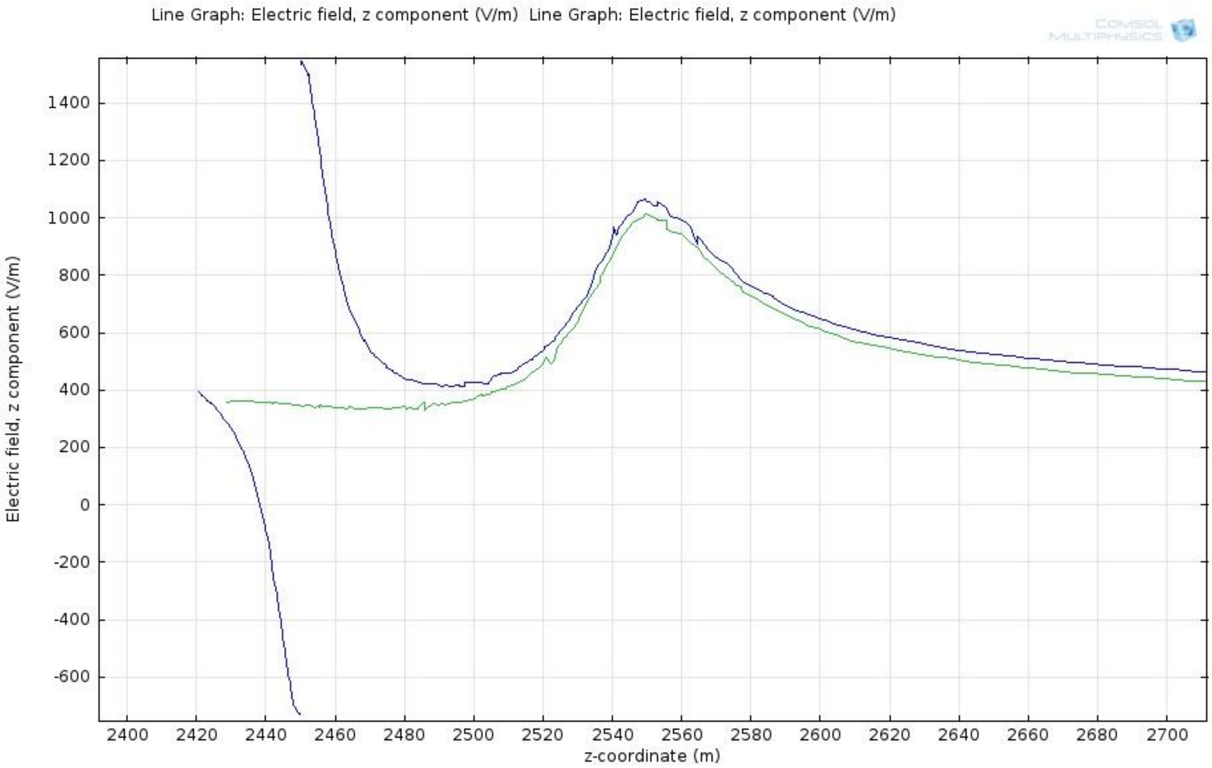


Figure 8 Nuage à 5.5km de la tour

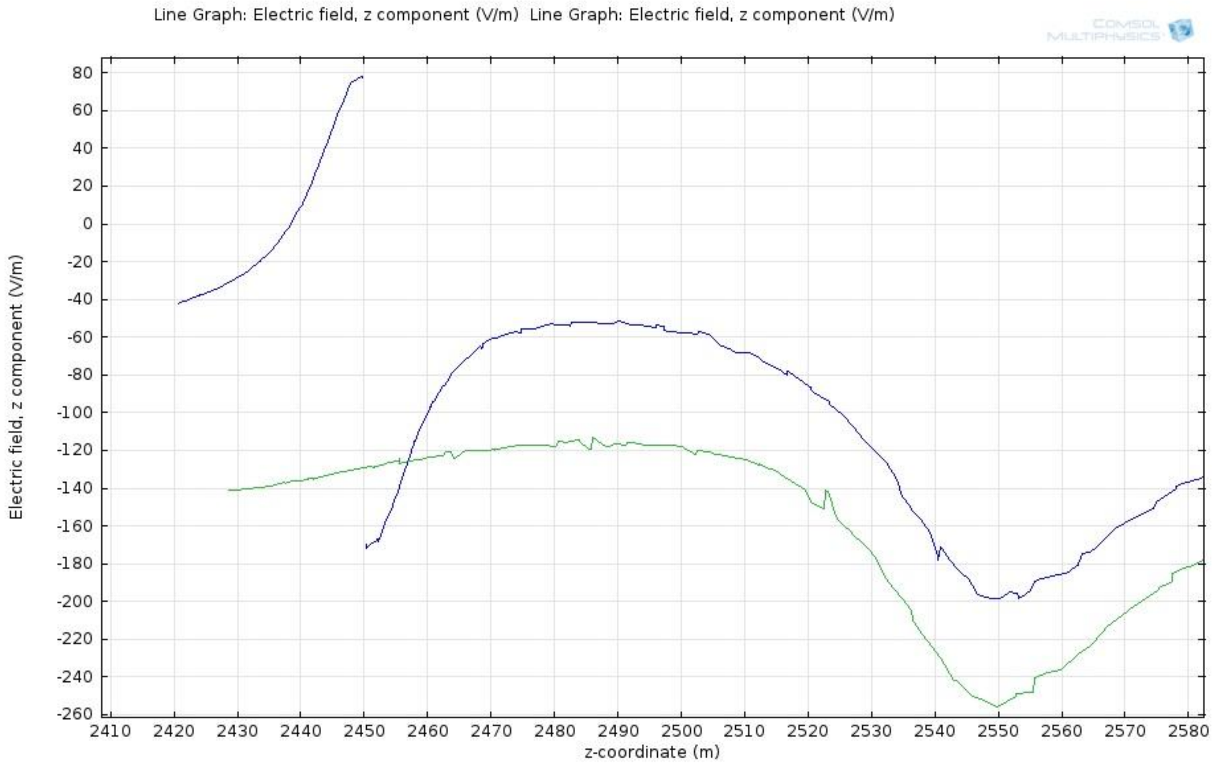


Figure 9Nuage à 6km de la tour

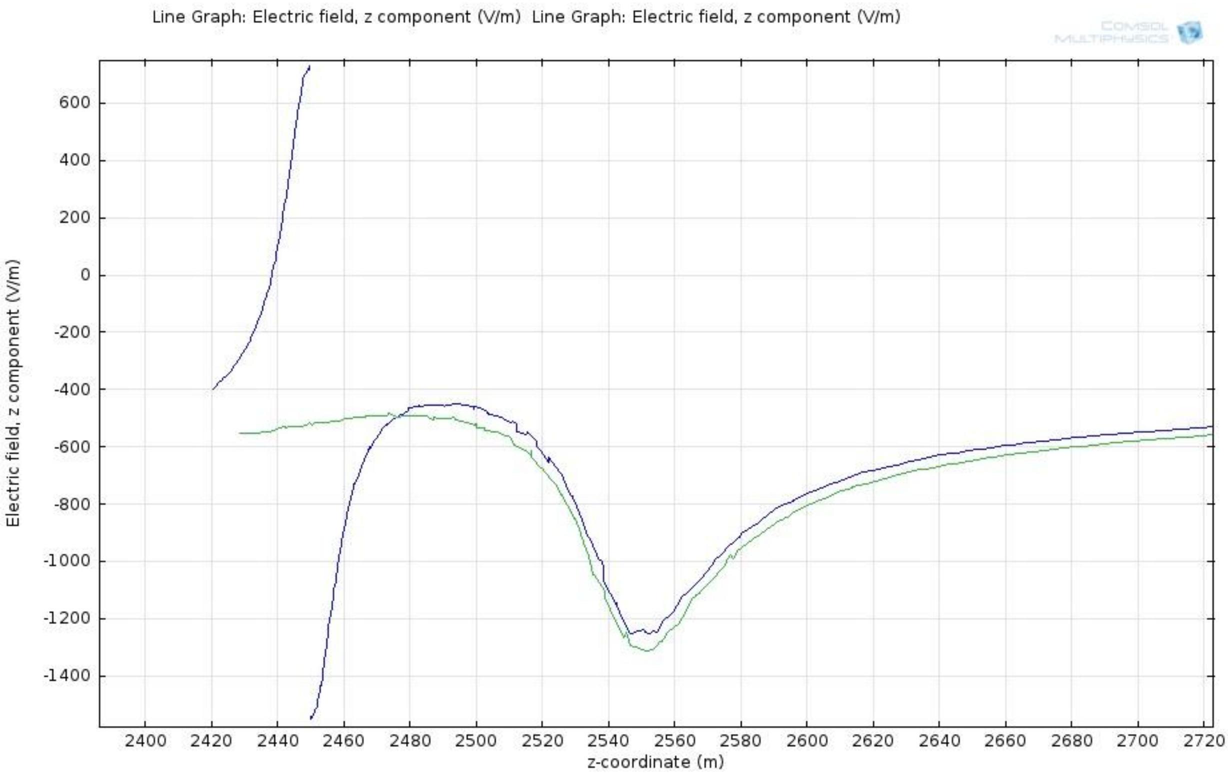


Figure 10 Nuage à 6.5km de la tour

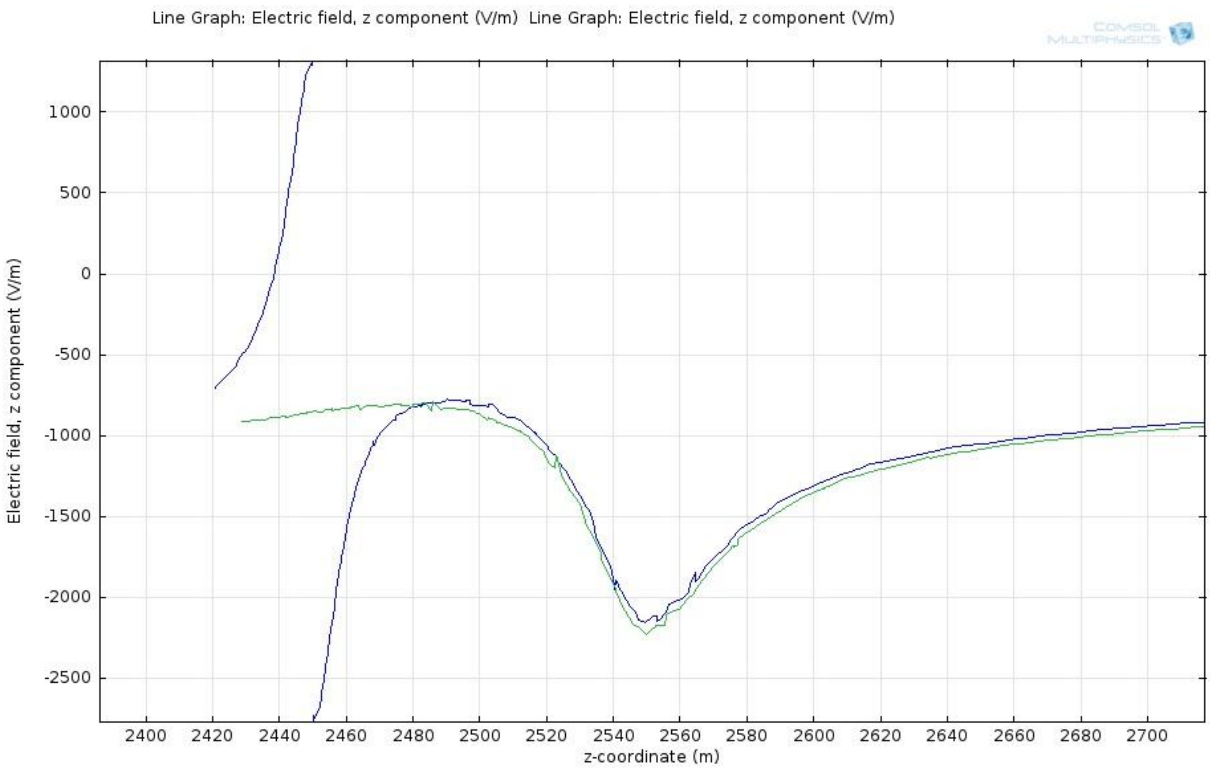


Figure 11 Nuage à 7km de la tour

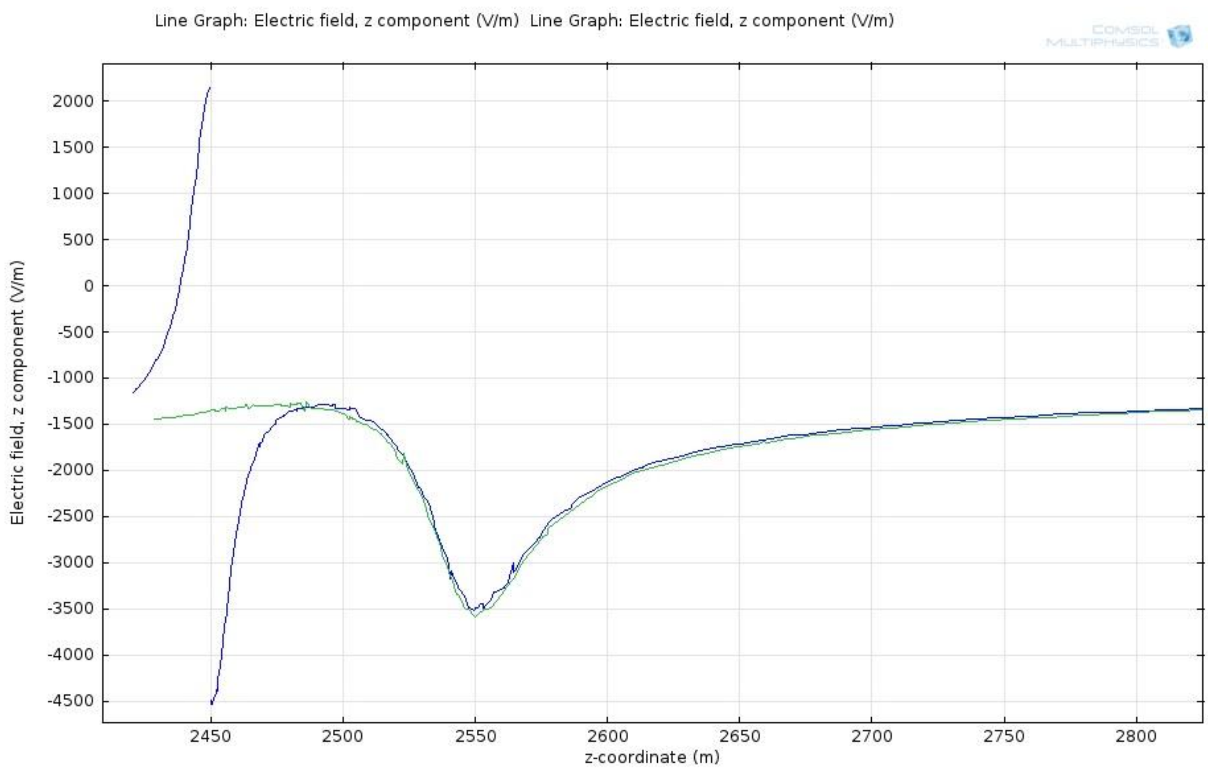


Figure 12 Nuage à 8km de la tour

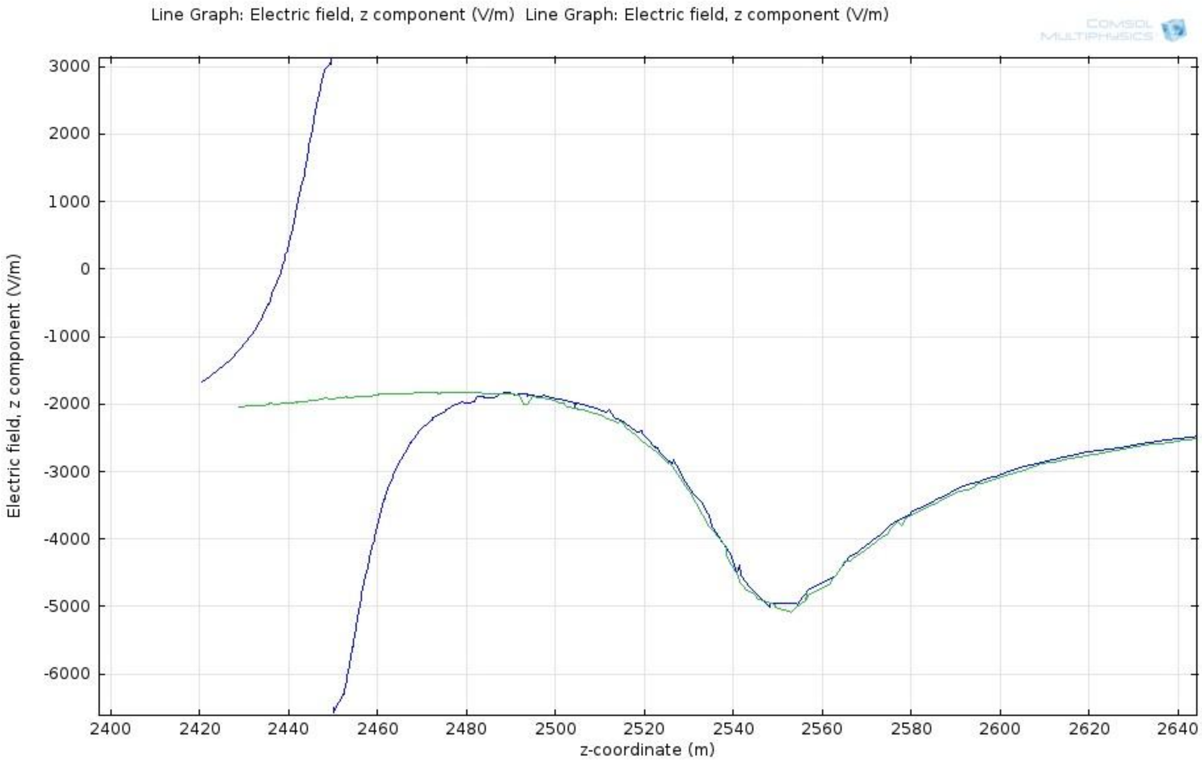
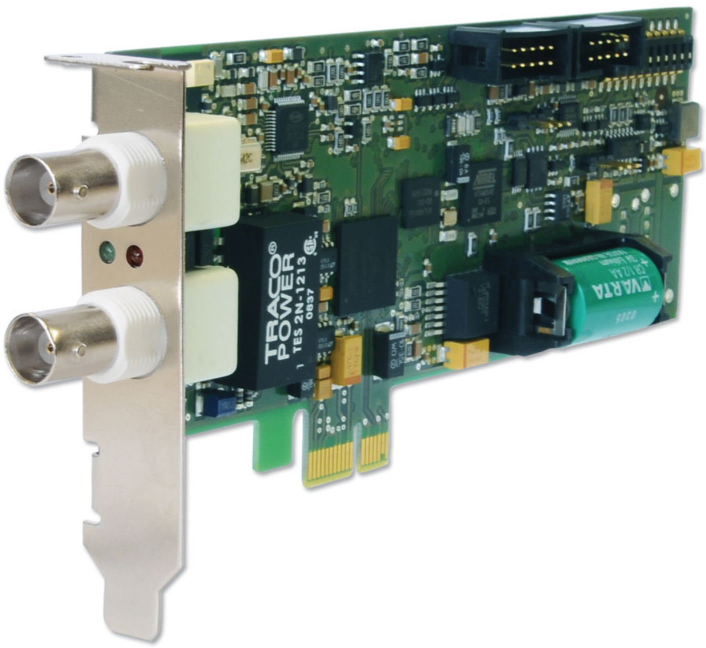


Figure 13 Nuage à 10km de la tour

Annexe 6

Datasheets

Jérôme Lovey, TD - 2012



MANUAL

GPS180PEX

Satellite controlled Radio Clock

14th February 2011

Meinberg Radio Clocks GmbH & Co. KG

Table of Contents

1 Impressum

Meinberg Radio Clocks GmbH & Co. KG
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Mail: info@meinberg.de

Date: 2011-01-10

2 Content of the USB stick

The included USB stick contains a driver program that keeps the computer´s system time synchronous to the received time. If the delivered stick doesn't include a driver program for the operating system used, it can be downloaded from:

http://www.meinberg.de/german/sw/

On the USB stick there is a file called "readme.txt", which helps installing the driver correctly.

3 Powering up the system

Installing the GPS180PEX in your computer
The computer has to be turned off and its case must be opened. The radio clock can be installed in any PCI Express slot not used yet. The rear plane must be removed before the board can be plugged in carefully. The computer´s case should be closed again and the antenna can be connected to the coaxial plug at the clock's rear slot cover. After the computer has been restarted, the monitor software can be run in order to check the clock's configuration.The computer´s case should be closed again and the antenna must be connected to the appropriate connector.

Every PCI Express board is a plug&play board. After power-up, the computer's BIOS assigns resources like I/O ports and interrupt numbers to the board, the user does not need to take care of the assignments. The programs shipped with the board retrieve the settings from the BIOS.

After the board has been mounted and the antenna has been connected, the system is ready to operate. About 10 seconds after power-up the receiver´s TCXO operates with the required accuracy. If the receiver finds valid almanac and ephemeris data in its battery buffered memory and the receiver´s position has not changed significantly since its last operation the receiver can find out which satellites are in view now. Only a single satellite needs to be received to synchronize and generate output pulses, so synchronization can be achieved at least one minute after power-up. After 20 minutes of operation the TCXO has achieved its final accuracy and the generated frequencies are within the specified tolerances.

If the receiver position has changed by some hundred kilometers since last operation, the satellites´ real elevation and Doppler might not match those values expected by the receiver thus forcing the receiver to start scanning for satellites. This mode is called Warm Boot because the receiver can obtain ID numbers of existing satellites from the valid almanac. When the receiver has found four satellites in view it can update its new position and switch to normal operation. If the almanac has been lost because the battery had been disconnected the receiver has to scan for a satellite and read in the current almanacs. This mode is called Cold Boot. It takes 12 minutes until the new almanac is complete and the system switches to Warm Boot mode scanning for other satellites. In the default mode of operation, neither pulse outputs nor the serial ports will be enabled after power-up until synchronization has been achieved.

However, it is possible to configure some or all of those outputs to be enabled immediately after power-up. If the system starts up in a new environment (e. g. receiver position has changed or new power supply) it can take some minutes until the TCXO´s output frequency has been adjusted. Up to that time accuracy of frequency drops to 10-8 reducing the accuracy of pulses to $+$-2μs.

3.1 Mounting the GPS Antenna

The GPS satellites are not stationary, but circle round the globe with a period of about 12 hours. They can only be received if no building is in the line-of-sight from the antenna to the satellite, so the antenna/downconverter unit must be installed in a location that has as clear a view of the sky as possible. The best reception is achieved when the antenna has a free view of 8° angular elevation above the horizon. If this is not possible, the antenna should be installed with the clearest free view to the equator, because the satellite orbits are located between latitudes 55° North and 55° South. If this is not possible, you may experience difficulty receiving the four satellites necessary to complete the receiver's position solution.

The unit can be mounted using a pole with a diameter up to 60 mm. A standard coaxial cable with 50 Ω impedance (e.g. RG58C) should be used to connect the antenna/converter unit to the receiver. Cable thinner than RG58 should be avoided due to its higher DC resistance and RF attenuation. When using the optional antenna diplexer the total length of one antenna line between antenna, diplexer and receiver must not be longer than 300 m. If a cable with less attenuation is used its length may be increased accordingly (e.g. 700 m with RG213).

Up to four GPS180 receivers can be run with one antenna/downconverter unit by using an optional antenna splitter. The total length of one antenna line between antenna, splitter and receiver must not be longer than the max. length shown in the table above. The position of the splitter in the antenna line does not matter.

High voltage protectors must be installed directly after reaching the indoors. The optional delivered protection kit is not for outdoor usage.

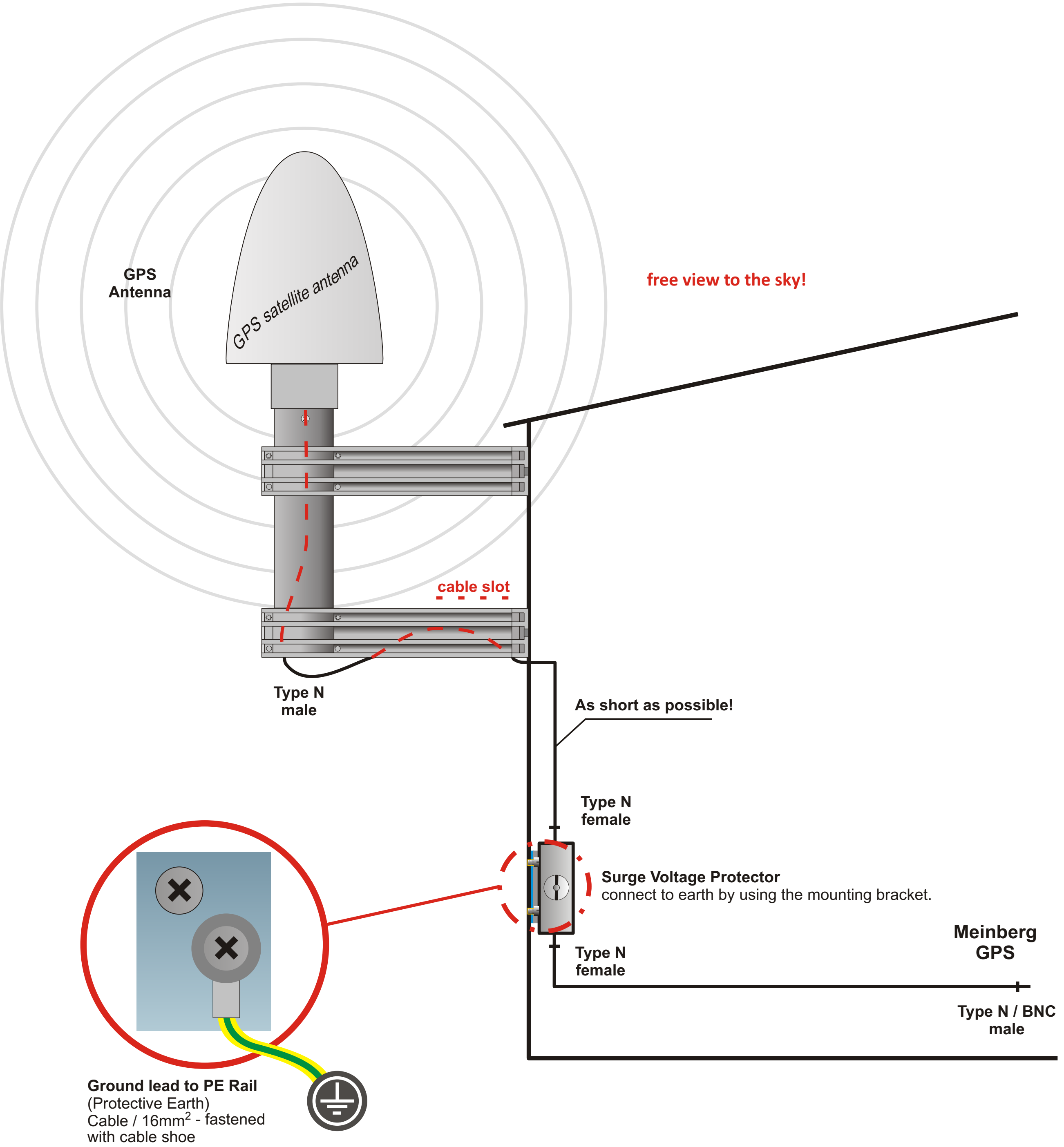
3.1.1 Example:

Type of cable	**diameter Ø [mm]**	**Attenuation at 100MHz [dB]/100m**	**max lenght. [m]**
RG58/CU	5mm	17	300 (1)
RG213	10.5mm	7	700 (1)

(1)This specifications are made for antenna/converter units produced after January, 2005
The values are typically ones; the exact ones are to find out from the data sheet of the used cable

3.1.2 Antenna Short-Circuit Assembly with surge voltage protection

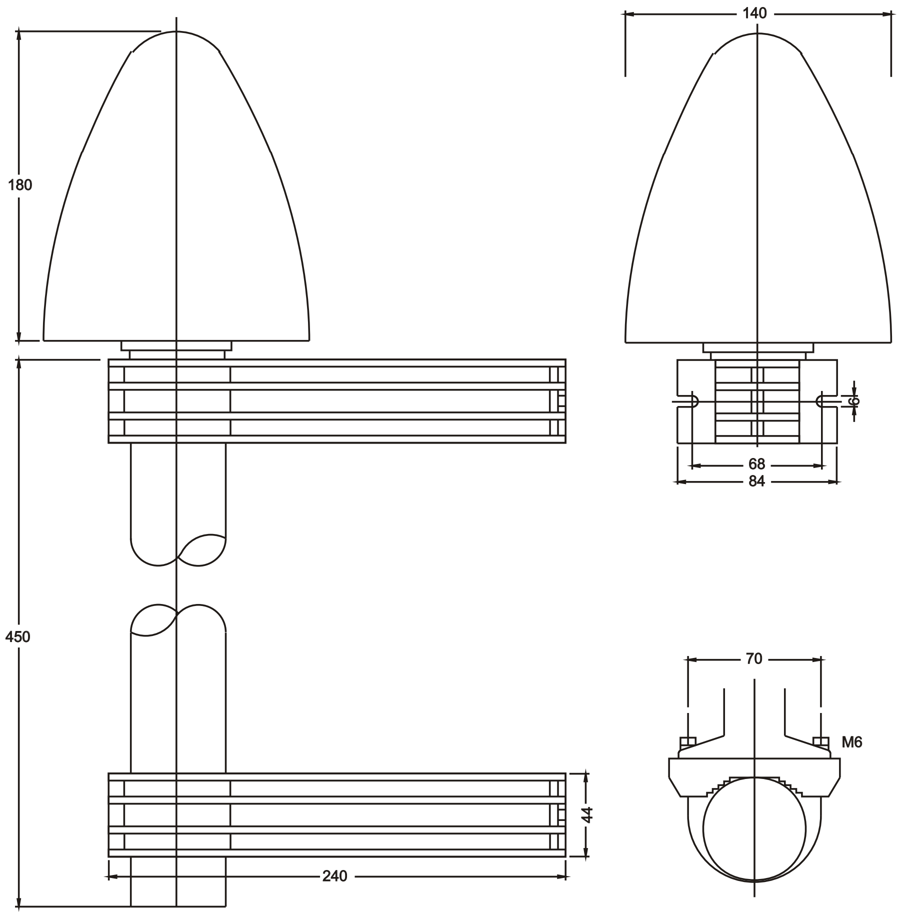
Optional a surge voltage protector for coaxial lines is available. The shield has to be connected to earth as short as possible by using the included mounting bracket. Standard you connect the antenna converter directly with the antenna cable to the system.



3.2 Technical Specifications GPS Antenna

ANTENNA:	dielectrical patch antenna,	25 x 25 mm
	receive frequency:	1575.42 MHz
BANDWITH:	9 MHz	
CONVERTER:	local oscillator to	
	converter frequency:	10 MHz
	first IF frequency:	35.4 MHz
POWER REQUIREMENTS:	12V ... 18V, @ 100mA (provided via antenna cable)	
CONNECTOR:	N-Type, female	
AMBIENT TEMPERATURE:	-40 ... +65°C	
HOUSING:	ABS plastic case for outdoor installation (IP66)	

Physical Dimension:



4 General information

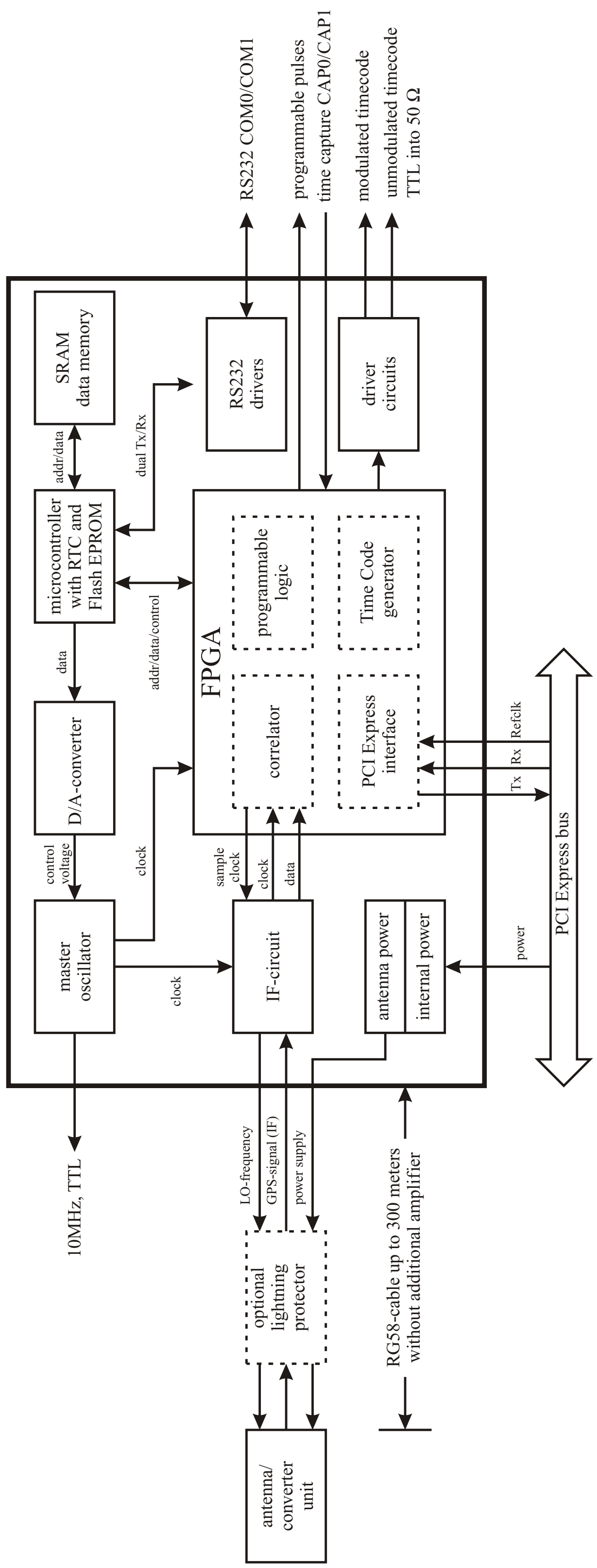
The satellite clocks made by Meinberg have been designed to provide extremely precise time to their users. The clocks have been developed for applications where conventional radio clocks can´t meet the growing requirements in precision. High precision available 24 hours a day around the whole world is the main feature of the new system which receives its information from the satellites of the Global Positioning System.

The Global Positioning System (GPS) is a satellite-based radio-positioning, navigation, and time-transfer system. It was installed by the United States Department of Defense and provides two levels of accuracy: The Standard Positioning Service (SPS) and the Precise Positioning Service (PPS). While PPS is encrypted and only available for authorized (military) users, SPS has been made available to the general public.

GPS is based on accurately measuring the propagation time of signals transmitted from satellites to the user´s receiver. A nominal constellation of 24 satellites together with some active spares in six orbital planes 20,000 km over ground provides a minimum of four satellites to be in view 24 hours a day at every point of the globe. Four satellites need to be received simultaneously if both receiver position (x, y, z) and receiver clock offset from GPS system time must be computed. All the satellites are monitored by control stations which determine the exact orbit parameters as well as the clock offset of the satellites´ on-board atomic clocks. These parameters are uploaded to the satellites and become part of a navigation message which is retransmitted by the satellites in order to pass that information to the user´s receiver.

The high precision orbit parameters of a satellite are called ephemeris parameters whereas a reduced precision subset of the ephemeris parameters is called a satellite´s almanac. While ephemeris parameters must be evaluated to compute the receiver´s position and clock offset, almanac parameters are used to check which satellites are in view from a given receiver position at a given time. Each satellite transmits its own set of ephemeris parameters and almanac parameters of all existing satellites.

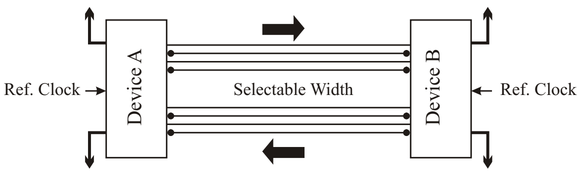
5 Blockdiagramm GPS180PEX



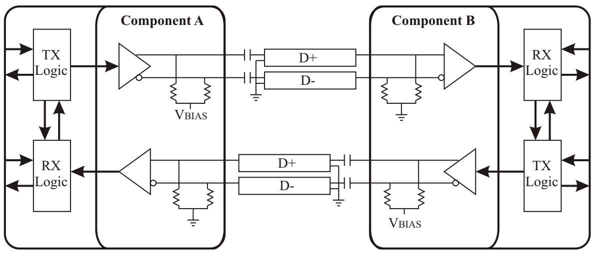
6 PCI Express (PCIe)

The main technical inovation of PCI Express is a serial data transmission compared to the parallel interfaces of other computer bus systems like ISA, PCI and PCI-X.

PCI Express defines a serial point-to-point connection, the so-called Link:

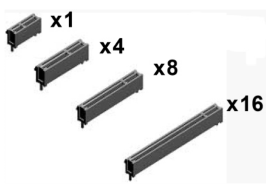


The data transfer within a Link is done via Lanes, representing one wire pair for sending and one wire pair for receiving data:



This design leads to a full duplex connection clocked with 2.5 GHz capable of transfering a data volume of 250 MB/s per lane in each direction. Higher bandwith is implemented by using multiple lanes silmutaneously. A PCI Express x16 slot for example uses sixteen lanes providing a data volume of 4 GB/s. For comparison: when using conventional PCI the maximum data transfer rate is 133 MB/s, PCI-X allows 1 GB/s but only in one direction respectively. A PCIe expansion board (x1 like Meinberg GPS receivers for example) can always be used in slots with a higher lane width (x4, x8, x16):

Interoperability				
Slot	x1	x4	x8	x16
Card				
x1	Yes	Yes	Yes	Yes
x4	No	Yes	Yes	Yes
x8	No	No	Yes	Yes
X16	No	No	No	Yes



One of the strong points of PCI Express is the 100% software compatibility to the well known PCI bus, leading to a fast spreading. The computer and the operating system are „seeing“ the more powerfull PCIe bus just as the convetional PCI bus without any software update.

7 GPS180PEX features

The board GPS180PEX is designed as a „low profile" board for computers with PCI Express interface. The rear slot cover integrates the antenna connector, a BNC connector for modulated time codes, two status LEDs and a 9pin SUB-D male connector. The card can be equipped with the delivered low profile cover. The I/O signals, available over a D-Sub plugs (RS-232 - PPS, PPM), are not available in this case.

The antenna/converter unit is connected to the receiver by a 50Ω coaxial cable with length up to 300m (when using RG58 cable). Power is supplied to the unit DC insulated across the antenna cable. Optionally, an over voltage protection and an antenna distributor are available. The antenna distributor can be used to operate up to 4 Meinberg GPS receivers using a single antenna/converter unit.

The navigation message coming in from the satellites is decoded by satellite clock's microprocessor in order to track the GPS system time with an accuracy of better than 250nsec. Compensation of the RF signal´s propagation delay is done by automatic determination of the receiver´s position on the globe. A correction value computed from the satellites´ navigation messages increases the accuracy of the board´s temperature compensated master oscillator (TCXO) to +/- 5E-9 and automatically compensates the TCXO´s aging. The last recent value is restored from the nonvolatile memory at power-up. Optionally, the clock is also available with a higher precision time base.

7.1 Time zone and daylight saving

GPS system time differs from the universal time scale (UTC) by the number of leap seconds which have been inserted into the UTC time scale after GPS has been initiated in 1980. The current number of leap seconds is part of the navigation message supplied by the satellites, so the satellite clock´s internal real time is based on UTC. Conversion to local time including handling of daylight saving year by year can be done by the receiver´s microprocessor. For Germany, the local time zone is UTC + 3600 sec for standard time and UTC + 7200 sec if daylight saving is in effect.

The clock's microprocessor determines the times for start and end of daylight saving time by a simple algorithm e. g. for Germany:

Start of DST is on the first Sunday after March, 25th, at 2 o'clock standard time.
End of DST is on the first Sunday after October, 25th, at 3 o'clock daylight time.

The monitoring software shipped with the board can be used to configure the time zone and daylight savings parameters easily. Switching to daylight saving time is inhibited if for both start and end of daylight saving the parameters are exactly the same.

The timecode (IRIG, AFNOR, IEEE) generated by GPS180PEX is available with these settings or with UTC as reference. This can be set by the monitor program.

7.2 Asynchronous serial ports

Two asynchronous serial interfaces (RS232) called COM0 and COM1 are available to the user. Only COM0 is available at the rear panel slot cover, COM1 must use another submin-D connector which can optionally be connected to the 5 pin jumper block on the board. The monitoring program can be used to configure the outputs. In the default mode of operation, the serial outputs are disabled until the receiver has synchronized after power-up. However, they can be configured to be enabled immediately after power-up.

Transmission speed, framing and mode of operation can be configured individually for each port. Both of the ports can be configured to transmit either time strings (once per second, once per minute, or on request with

ASCII ´?´ only), or to transmit capture strings (automatically when available, or on request). The format of the output strings is ASCII, see the technical specifications at the end
of this document for details.

7.3 Time capture inputs

The board provides two time capture inputs called User Capture 0 and 1 (CAP0 and CAP1) which can be mapped to pins at the 9 pin connector at the rear panel. These inputs can be used to measure asynchronous time events. A falling TTL slope at one of these inputs lets the microprocessor save the current real time in its capture buffer. From the buffer, an ASCII string per capture event can be transmitted via COM1 or displayed using the monitoring program. The capture buffer can hold more than 500 events, so either a burst of events with intervals down to less than 1.5 msec can be recorded or a continuous stream of events at a lower rate depending on the transmission speed of COM1 can be measured. The format of the output string is described in the technical specifications at the end of this document. If the capture buffer is full a message "** capture buffer full" is transmitted, if the interval between two captures is too short the warning "** capture overrun" is being sent via COM1.

7.4 Pulse and frequency outputs

The pulse generator of the satellite controlled clock GPS180PEX contains three independent channels (PPO0, PPO1, PPO2). These TTL outputs can be mapped to pins at the 9-pin connector at the rear slot cover by using a DIL switch. The pulse generator is able to provide a multitude of different pulses, which are configured with the monitor program. The active state of each channel is invertible, the pulse duration settable between 10 msec and 10 sec in steps of 10 msec. In the default mode of operation the pulse outputs are disabled until the receiver has synchronized after power-up. However, the system can be configured to enable those outputs immediately after power-up.

Synthesizer
The programmable pulse outputs are able to generates a frequency from 1/8 Hz up to 10 MHz synchronous to the internal timing frame. The phase of this output can be shifted from -360° to +360° for frequencies less than 10 kHz.

The following modes can be configured for each channel independently:

Timer mode: Three on- and off-times per day per channel programmable

Cyclic mode: Generation of periodically repeated pulses.
A cycle time of two seconds would generate a pulse at
0:00:00, 0:00:02, 0:00:04 etc.

DCF77-Simulation mode: The corresponding output simulates the DCF77 time telegram.
The time marks are representing the local time as configured by the user.

Single Shot Mode: A single pulse of programmable length is generated once a day at a programmable point of time

Per Sec., Per Min.
Per Hr. modes: Pulses each second, minute or hour

Synthesizer Frequency output 1/8 Hz up to 10 MHz

Time Codes Generation of Time Codes as described in chapter "Time Codes"

Status: One of three status messages can be emitted:
'position OK': The output is switched on if the receiver was able to compute its position
'time sync': The output is switched on if the internal timing is synchronous to the GPS-system
'all sync': Logical AND of the above status messages.
The output is active if position is calculated AND the

timing is synchronized

Idle-mode: The output is inactive

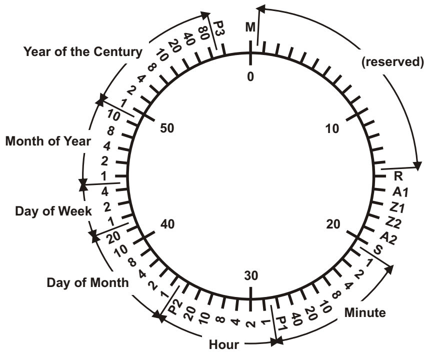
The default configuration for the pulse outputs is:
———————————————————————————

PPO0: Pulse each second (PPS), active HIGH, pulse duration 200 msec
PPO1: Pulse each minute (PPM), active HIGH, pulse duration 200 msec
PPO2: DCF77 Simulation

A TTL level master frequency of 10 MHz is derived from the TCXO. By default, this frequency is available only at the 5 pin contact strip of the board.

7.5 DCF77 Emulation

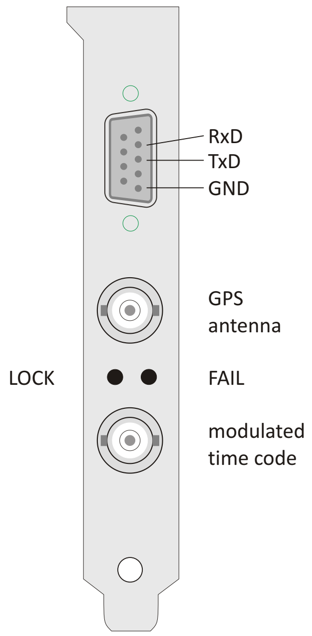
The GPS180PEX satellite controlled clock generates TTL level time marks (active HIGH) which are compatible with the time marks spread by the German long wave transmitter DCF77. This long wave transmitter installed in Mainflingen near Frankfurt/Germany transmits the reference time of the Federal Republic of Germany: time of day, date of month and day of week in BCD coded second pulses. Once every minute the complete time information is transmitted. However, GPS180PEX generates time marks representing its local time as configured by the user, including announcement of changes in daylight saving and announcement of leap seconds. The coding sheme is given below:



M	Start of Minute (0.1 s)	
R	RF Transmission via secondary antenna	
A1	Announcement of a change in daylight saving	
Z1, Z2	Time zone identification	
	Z1, Z2 = 0, 1:	Daylight saving disabled
	Z1, Z2 = 1, 0:	Daylight saving enabled
A2	Announcement of a leap second	
S	Start of time code information	
P1, P2, P3	Even parity bits	

Time marks start at the beginning of new second. If a binary "0" is to be transmitted, the length of the corresponding time mark is 100 msec, if a binary "1" is transmitted, the time mark has a length of 200 msec. The information on the current date and time as well as some parity and status bits can be decoded from the time marks of the 15th up to the 58th second every minute. The absence of any time mark at the 59th second of a minute signals that a new minute will begin with the next time mark. The DCF emulation output is enabled immediately after power-up.

8 Connectors and LEDs in the rear slot cover



The coaxial antenna connector, two status LEDs and a 9 pin sub D connector can be found in the rear slot cover. (see figure). The upper, green LED (LOCK) is turned on when after power-up the receiver has acquired at least four satellites and has computed its position. In normal operation the receiver position is updated continuously as long
as at least four satellites can be received.

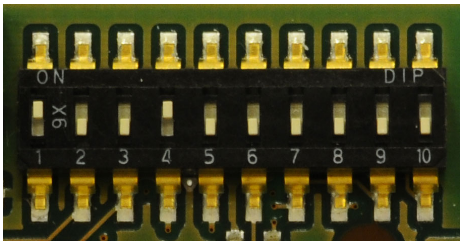
The lower, red LED (FAIL) is turned on after power-up until the receiver has synchronized or if a severe error occurs during operation.

The 9 pin sub D connector is wired to the GPS170PEX's serial port COM0. Pin assignment can be seen from the figure beside. This port can not be used as serial port for the computer. Instead, it can be uses to send out Meinberg's standard time string to an external device.

A DIL switch on the board can be used to wire some TTL inputs or outputs (0..5V) to some connector pins. In this case, absolute care must be taken if another device is connected to the port, because voltage levels of -12V through +12V (as commonly used with RS-232 po rts) at TTL inputs or outputs may damage the radio clock.

8.1 Configuring the 9 pin connector

By default only the signals needed for the serial port COM0 are mapped to the pins of the connector. Whenever one of the additional signals shall be used, the signal must be mapped to a pin by putting the appropriate lever of the DIL switch in the ON position. The table below shows the pin assignments for the connector and the DIL switch lever assigned to each of the signals. Care must be taken when mapping a signal to Pin 1, Pin 4 or Pin 7 of the connector, because one of two different signals can be mapped to these Pins. Only one switch may be put in the ON position in this case:



Pin 1: DIL 1 or DIL 8 ON
Pin 4: DIL 5 or DIL 10 ON
Pin 7: DIL 3 or DIL 7 ON

The figure left shows DIL1 and DIL4 ON =>
PIN1: VCC out
PIN8: PPO0 - PPS out

Those signals which do not have a lever of the DIL switch assigned are always available at the connector:

D-SUB-Pin	Signal	Signal level	DIL-switch
1	VCC out	+5V	1
1	PPO0 (PPS) out	RS232	8
2	RxD in	RS232	-
3	TxD out	RS232	-
4	PPO1 (PPM) out	TTL	5
4	10MHz out	TTL	10
5	GND	-	-
6	CAP0 in	TTL	2
7	CAP1 in	TTL	3
7	IRIG DC out	TTL into 50 Ω	7
8	PPO0 (PPS) out	TTL	4
9	PPO2 (DCF) out	TTL	9

9 Firmware updates

Whenever the on-board software must be upgraded or modified, the new firmware can be downloaded to the internal flash memory via the radio clock's serial port COM0. There is no need to open the computer case and insert a new EPROM.

A loader program shipped together with the file containing the image of the new firmware sends the new firmware from one of the computer's serial ports to the clock's serial port COM0. The contents of the program memory will not be modified until the loader program has sent the command to erase the flash memory. The system will be ready to operate again after the computer has been turned off and then on again.

10 Time codes

The transmission of coded timing signals began to take on widespread importance in the early 1950´s. Especially the US missile and space programs were the forces behind the development of these time codes, which were used for the correlation of data. The definition of time code formats was completely arbitrary and left to the individual ideas of each design engineer. Hundreds of different time codes were formed, some of which were standardized by the „Inter Range Instrumentation Group“ (IRIG) in the early 60´s.

Except these „IRIG Time Codes“ other formats, like NASA36, XR3 or 2137, are still in use. The board GPS170PEX however generates the IRIG-B, AFNOR NFS 87- 500 code as well as IEEE1344 code which is an IRIG-B123 coded extended by information for time zone, leap second and date. If desired other formats are available.

10.1 The time code generator

The board GPS170PEX generates modulated and un-modulated timecodes. Modulated signals are transmitting the information by varying the amplitude of a sine wave carrier, un-modulated timecodes are transmitted by pulse duration modulation of a DC-signal (TTL in case of GPS170PEX), see chapter „IRIG standard format“ for details.

The sine wave carrier needed for modulated signals is generated in a digital way by a programmable logic device on the board. The frequency of this signal is derived from the main oscillator of GPS170PEX, which is disciplined by the GPS-system.

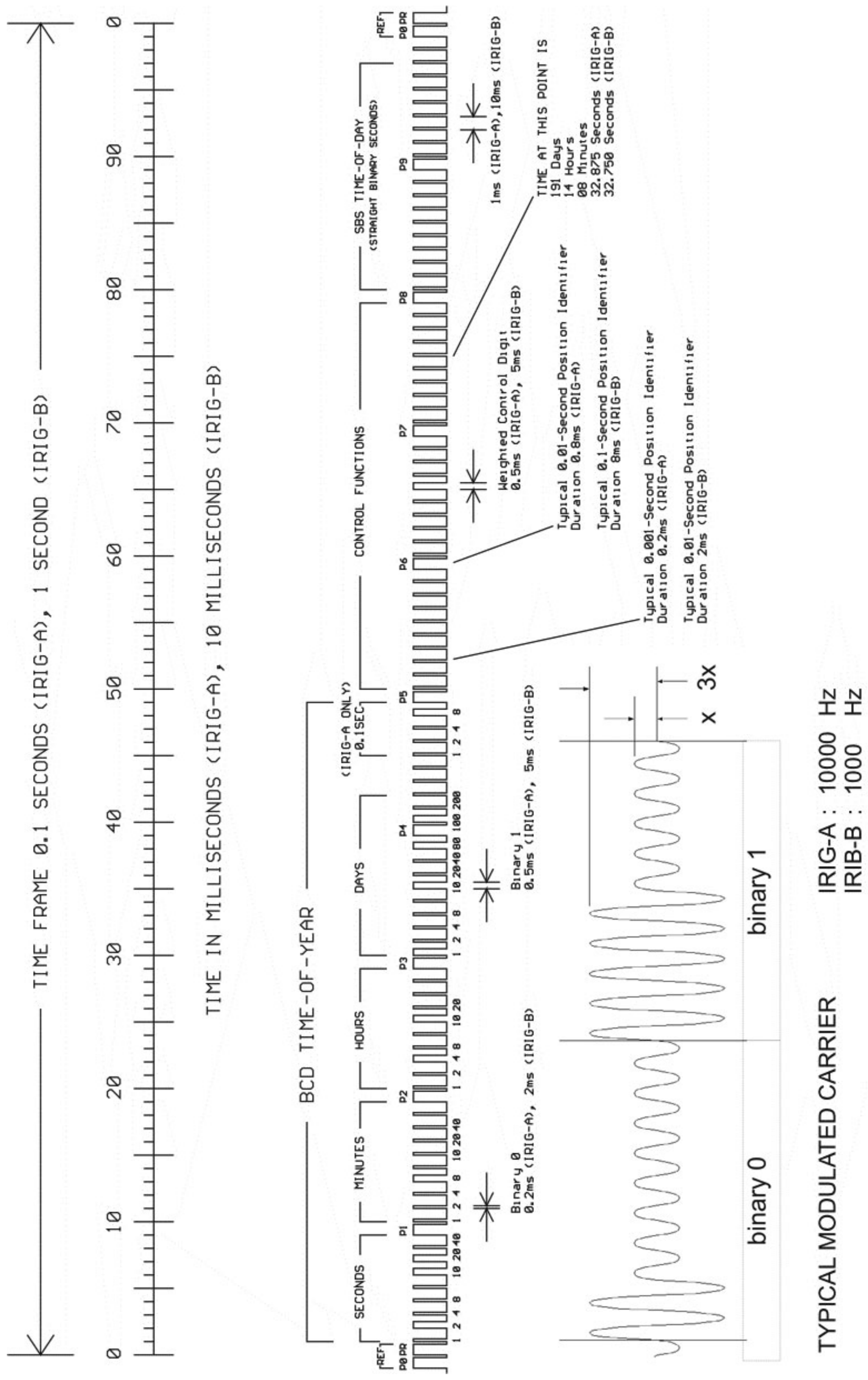
This leads to a sine wave carrier with high accuracy. Transmission of date is synchronized by the PPS (pulse per second) derived from the GPS-system. The modulated time code has an amplitude of 3Vpp (MARK) and 1Vpp (SPACE) into 50 O. The number of MARK-amplitudes within ten periods of the carrier defines the coding:

a) binary „0“ : 2 MARK-amplitudes, 8 SPACE-amplitudes
b) binary „1“ : 5 MARK-amplitudes, 5 SPACE-amplitudes
c) position-identifier : 8 MARK-amplitudes, 2 SPACE-amplitudes

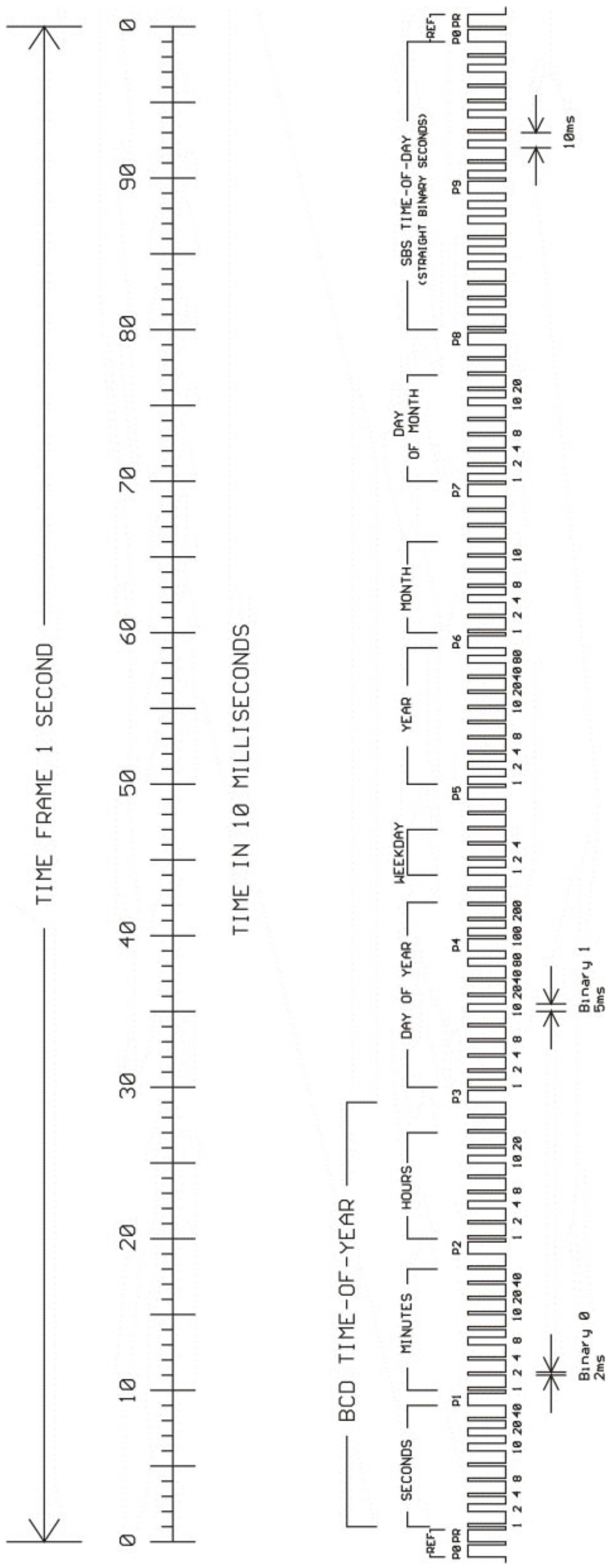
The DC-signal has the following pulse durations accordingly:

a) binary „0“ : 2 msec
b) binary „1“ : 5 msec
c) position-identifier : 8 msec

10.2 IRIG Standard Format



10.3 AFNOR Standard Format



10.4 Assignment of CF Segment in IEEE1344 Code

Bit No.	Designation	Description
49	Position Identifier P5	
50	Year BCD encoded 1	
51	Year BCD encoded 2	low nibble of BCD encoded year
52	Year BCD encoded 4	
53	Year BCD encoded 8	
54	empty, always zero	
55	Year BCD encoded 10	
56	Year BCD encoded 20	high nibble of BCD encoded year
57	Year BCD encoded 40	
58	Year BCD encoded 80	
59	Position Identifier P6	
60	LSP - Leap Second Pending	set up to 59s before LS insertion
61	LS - Leap Second	0 = add leap second, 1 = delete leap second 1.)
62	DSP - Daylight Saving Pending	set up to 59s before daylight saving changeover
63	DST - Daylight Saving Time	set during daylight saving time
64	Timezone Offset Sign	sign of TZ offset 0 = '+', 1 = '-'
65	TZ Offset binary encoded 1	
66	TZ Offset binary encoded 2	Offset from IRIG time to UTC time.
67	TZ Offset binary encoded 4	Encoded IRIG time plus TZ Offset equals UTC at all times!
68	TZ Offset binary encoded 8	
69	Position Identifier P7	
70	TZ Offset 0.5 hour	set if additional half hour offset
71	TFOM Time figure of merit	
72	TFOM Time figure of merit	time figure of merit represents approximated clock error. 2.)
73	TFOM Time figure of merit	0x00 = clock locked, 0x0F = clock failed
74	TFOM Time figure of merit	
75	PARITY	parity on all preceding bits incl. IRIG-B time

1.) current firmware does not support leap deletion of leap seconds
2.) TFOM is cleared, when clock is synchronized first after power up. see chapter Selection of generated timecode

10.5 Generated Time Codes

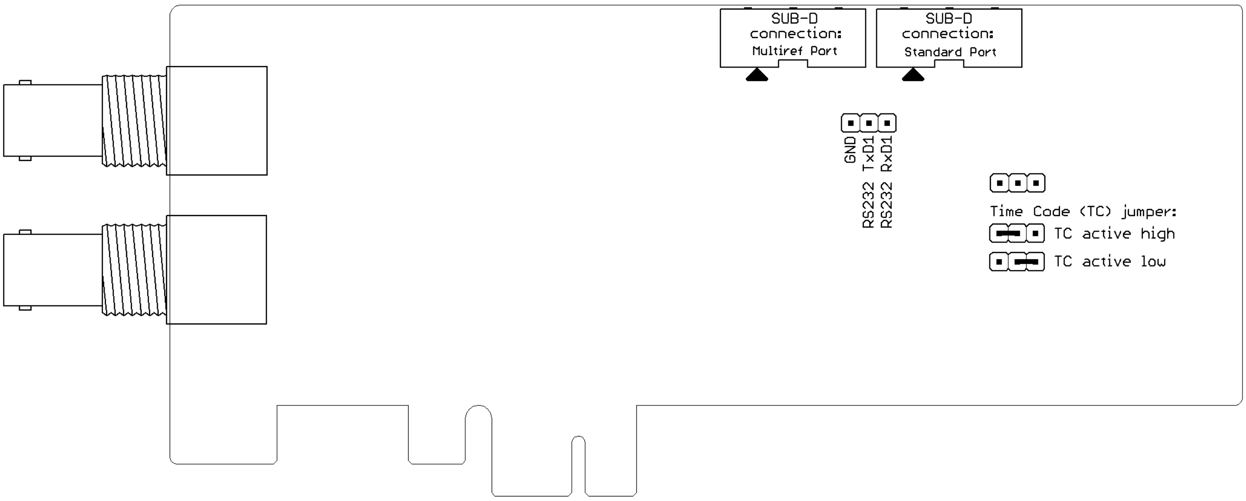
Besides the amplitude modulated sine wave signal, the board also provides unmodulated DC-Level Shift TTL output in parallel. Thus six time codes are available.

a)	B002:	100 pps, DCLS signal, no carrier BCD time-of-year
b)	B122:	100 pps, AM sine wave signal, 1 kHz carrier frequency BCD time-of-year
c)	B003:	100 pps, DCLS signal, no carrier BCD time-of-year, SBS time-of-day
d)	B123:	100 pps, AM sine wave signal, 1 kHz carrier frequency BCD time-of-year, SBS time-of-day
e)	B006:	100 pps, DCLS Signal, no carrier BCD time-of-year, Year
f)	B126:	100 pps, AM sine wave signal, 1 kHz carrier frequency BCD time-of-year, Year
g)	B007:	100 pps, DCLS Signal, no carrier BCD time-of-year, Year, SBS time-of-day
h)	B127:	100 pps, AM sine wave signal, 1 kHz carrier frequency BCD time-of-year, Year, SBS time-of-day
i)	AFNOR:	Code according to NFS-87500, 100 pps, wave signal, 1kHz carrier frequency, BCD time-of-year, complete date, SBS time-of-day, Signal level according to NFS-87500
j)	IEEE1344:	Code according to IEEE1344-1995, 100 pps, AM sine wave signal, 1kHz carrier frequency, BCD time-of-year, SBS time-of-day, IEEE1344 extensions for date, timezone, daylight saving and leap second in control functions (CF) segment. (also see table 'Assignment of CF segment in IEEE1344 mode')
k)	C37.118	Like IEEE1344 - with turned sign bit for UTC-Offset

10.6 Selection of time code

The selection of timecode is done by the monitor software.

The un-modulated time code can be delivered as an active-high (default) or activelow signal by setting a jumper on the board GPS170PEX into the appropriate position:



11 Technical Specifications GPS180PEX

RECEIVER:	Six channel C/A code receiver with external antenna/converter unit	
ANTENNA:	Antenna/converter unit with remote power supply	
	refer to chapter "Technical specifications of antenna"	
POWER SUPPLY FOR ANTENNA:	15 VDC, continuous short circuit potection, automatic recovery	
	Isolation voltage 1000 VDC, provided via antenna cable	
ANTENNA INPUT:	Antenna circuit dc-insulated; dielectric strength: 1000V	
	Length of cable: refer to chapter "Mounting the Antenna	
TIME TO SYNCHRONIZATION:	one minute with known receiver position and valid almanac	
	12 minutes if invalid battery buffered memory	
PULSE OUTPUTS:	three programmable outputs, TTL level	
	Default settings:	
	active only ‚if sync‘	
	PPO0:	change of second (PPS)
		pulse duration 200 msec
		valid on rising edge
	PPO1:	change of minute (PPM)
		pulse duration 200 msec
		valid on rising edge
	PPO2:	DCF77 simulation
	Synthesizer	
	1/8 Hz to 10 MHz	base accuracy according to system accuracy
	1/8 Hz to 10 kHz	phase syncron with pulse per second
	10 kHz to 10 MHz	frequency deviation < 0.0047 Hz
ACCURACY OF PULSES:	better than +/- 250 nsec after synchronization and 20 minutes of operation	
	better than +/- 2 μsec during the first 20 minutes of operation	
	better than +/- 100nsec with optional OCXO MQ/HQ (see oscillator options)	
TIME CAPTURE INPUTS:	triggered on falling TTL slope	
	Interval of events: 1.5msec min., Resolution: 100ns	
FREQUENCY OUTPUTS:	10 MHz (TTL level)	
SYSTEM BUS INTERFACE:	Single lane (x1) PCI Express (PCIe) Interface	
	compatible to PCI Express specifications r1.0a	
DATA FORMAT:	Binary, byte serial	
SERIAL PORTS:	2 asynchronous serial ports (RS-232)	
	Baud Rate:	300 up to 19200
	Framing:	7N2, 7E1, 7E2, 8N1, 8N2, 8E1
	default setting:	

	COM0:	19200, 8N1 Meinberg Standard time string, per second
	COM1:	9600, 8N1 Capture string, automatically
TIME CODE OUTPUTS:	Unbalanced modulated sine wave signal: 3Vpp (MARK), 1Vpp (SPACE) into 50 ohm	
	DCLS-signal: TTL into 50 ohm, active-high or -low, selected by jumper	
	optionally optical output(instead of modulated sine wave):	
	optical power:	typ. 15μW
	optical connector:	ST-connector for GI 50/125μm or GI 62,5/125μm gradient fiber
POWER REQUIREMENT:	+3.3 V:	70 mA
	+12 V :	390 mA
	power supplies provided by PCI Express interface	
PHYSICAL DIMENSION:	standard height expansion board	
RF CONNECTOR:	female coaxial BNC-connectors for antenna and modulated time code	
AMBIENT TEMPERATURE:	0 ... 50°C	
HUMIDITY:	85% max.	

ACCURACY OF FREQUENCY AND PULSE OUTPUTS:

Oscillator Option	TCXO (standard)	OCXO LQ	OCXO MQ	OCXO HQ
short term stability (τ = 1 sec)	2E-9	1E-9	2E-10	5E-12
accuracy of PPS (pulse per second)	< +/- 250 nsec	< +/- 250 nsec	< +/- 100 ns	< +/- 100 ns
phase noise	1 Hz -60 dBc/Hz 10 Hz -90 dBc/Hz 100 Hz -120 dBc/Hz 1 kHz -130 dBc/Hz	1 Hz -60 dBc/Hz 10 Hz -90 dBc/Hz 100 Hz -120 dBc/Hz 1 kHz -130 dBc/Hz	1Hz -75dBc/Hz 10Hz -110dBc/Hz 100Hz -130dBc/Hz 1kHz -140dBc/Hz	1Hz < -85dBc/Hz 10Hz < -115dBc/Hz 100Hz < -130dBc/Hz 1kHz < -140dBc/Hz
accuracy free run, one day	+/- 1E-7 +/- 1 Hz (Note 1)	+/- 2E-8 +/- 0,2 Hz (Note 1)	+/- 1,5E-9 +/- 15mHz (Note1)	+/- 5E-10 +/- 5mHz (Note1)
accuracy free run, one year	+/- 1E-6 +/- 10 Hz (Note 1)	+/- 4E-7 +/- 4 Hz (Note 1)	+/- 1E-7 +/- 1Hz (Note1)	+/- 5E-8 +/- 0.5Hz (Note1)
accuracy GPS-synchronous averaged 24 h	+/- 1E-11	+/- 1E-11	+/- 5E-12	+/- 1E-12
accuracy of time free run, one day	+/- 4.3 msec	+/- 865 µs	+/- 65 µs	+/- 22 µs
accuracy of time free run, one year	+/- 16 sec	+/- 6.3 sec	+/- 1.6 s	+/- 788 ms
temperature dependant drift, free run	+/- 1E-6 (-20...70°C)	+/- 2 * 10 -7 (0...60°C)	+/- 5E-8 (-20...70°C)	+/- 1E-8 (5...70°C)

Note 1:
The accuracy in Hertz is based on the standard frequency of 10 MHz.
For example: Accuracy of TCXO (free run one day) is +/- 1E-7 * 10 MHz = +/- 1 Hz

The given values for the accuracy of frequency and time (not short term accuracy) are only valid for a constant ambient temperature ! A minimum time of 24h of GPS-synchronicity is required before free run starts.

11.1 Time Strings

11.1.1 Format of the Meinberg Standard Time String

The Meinberg Standard Time String is a sequence of 32 ASCII characters starting with the STX (start-of-text) character and ending with the ETX (end-of-text) character. The format is:

<STX>D:*dd.mm.yy;T:w;U:hh.mm.ss;uvxy*<ETX>

The letters printed in italics are replaced by ASCII numbers whereas the other characters are part of the time string. The groups of characters as defined below:

<STX>	Start-Of-Text, ASCII Code 02h		
	sending with one bit occuracy at change of second		
dd.mm.yy	the current date:		
	dd	day of month	(01..31)
	mm	month	(01..12)
	yy	year of	
	the century	(00..99)	
w	the day of		
	the week		(1..7, 1 = Monday)
hh.mm.ss	the current time:		
	hh	hours	(00..23)
	mm	minutes	(00..59)
	ss	seconds	(00..59, or 60 while leap second)

uv clock status characters (depending on clock type):

u:	'#'	GPS: clock is running free (without exact synchr.)
		PZF: time frame not synchronized
		DCF77: clock has not synchronized after reset
	' '	(space, 20h)
		GPS: clock is synchronous (base accuracy is reached)
		PZF: time frame is synchronized
		DCF77: clock has synchronized after reset
v:	'*'	GPS: receiver has not checked its position
		PZF/DCF77: clock currently runs on XTAL
	' '	(space, 20h)
		GPS: receiver has determined its position
		PZF/DCF77: clock is syncronized with transmitter

x time zone indicator:

'U'	UTC	Universal Time Coordinated, formerly GMT
' '	MEZ	European Standard Time, daylight saving disabled
	'S'	MESZ European Summertime, daylight saving enabled

y anouncement of discontinuity of time, enabled during last hour before discontinuity comes in effect:

'!'	announcement of start or end of daylight saving time
'A'	announcement of leap second insertion
' '	(space, 20h) nothing announced

<ETX> End-Of-Text, ASCII Code 03h

11.1.2 Format of the Meinberg Capture String

The Meinberg Capture String is a sequence of 31 ASCII characters terminated by a CR/LF (Carriage Return/Line Feed) combination. The format is:

CH*x*_ *tt.mm.jj*_ *hh:mm:ss.fffffff*<CR><LF>

The letters printed in italics are replaced by ASCII numbers whereas the other characters are part of the time string. The groups of characters as defined below:

x	0 or 1 corresponding on the number of the capture input
_	ASCII space 20h

dd.mm.yy the capture date:

dd	day of month	(01..31)
mm	month	(01..12)
yy	year of the century	(00..99)

hh:mm:ss.fffffff the capture time:

hh	hours	(00..23)
mm	minutes	(00..59)
ss	seconds	(00..59, or 60 while leap second)
fffffff	fractions of second, 7 digits	

<CR> Carriage Return, ASCII Code 0Dh

<LF> Line Feed, ASCII Code 0Ah

11.1.3 Format of the SAT Time String

The SAT Time String is a sequence of 29 ASCII characters starting with the STX (start-of-text) character and ending with the ETX (end-of-text) character. The format is:

<STX>*dd.mm.yy/w/hh:mm:ssxxxxuv*<ETX>

The letters printed in italics are replaced by ASCII numbers whereas the other characters are part of the time string. The groups of characters as defined below:

<STX>	Start-Of-Text, ASCII Code 02h sending with one bit occuracy at change of second		
dd.mm.yy	the current date:		
	dd	day of month	(01..31)
	mm	month	(01..12)
	yy	year of the century	(00..99)
	w	the day of the week	(1..7, 1 = Monday)
hh:mm:ss	the current time:		
	hh	hours	(00..23)
	mm	minutes	(00..59)
	ss	seconds	(00..59, or 60 while leap second)
xxxx	time zone indicator:		
	'UTC'	Universal Time Coordinated, formerly GMT	
	'MEZ'	European Standard Time, daylight saving disabled	
	'MESZ'	European Summertime, daylight saving enabled	
u	clock status characters:		
	'#'	clock has not synchronized after reset	
	' '	(space, 20h) clock has synchronized after reset	
v	anouncement of discontinuity of time, enabled during last hour before discontinuity comes in effect:		
	'!'	announcement of start or end of daylight saving time	
	' '	(space, 20h) nothing announced	
<CR>	Carriage Return, ASCII Code 0Dh		
<LF>	Line Feed, ASCII Code 0Ah		
<ETX>	End-Of-Text, ASCII Code 03h		

11.1.4 Format of the NMEA 0183 String (RMC)

The NMEA String is a sequence of 65 ASCII characters starting with the '$GPRMC' character and ending with the characters CR (carriage return) and LF (line-feed). The format is:

$GPRMC,*hhmmss.ss,A,bbbb.bb,n,lllll.ll,e,0.0,0.0,ddmmyy,0.0,a*hh*<CR><LF>

The letters printed in italics are replaced by ASCII numbers or letters where as the other characters are part of the time string. The groups of characters as defined below:

$	Start character, ASCII Code 24h		
	sending with one bit occuracy at change of second		
hhmmss.ss	the current time:		
	hh	hours	(00..23)
	mm	minutes	(00..59)
	ss	seconds	(00..59, or 60 while leap second)
	ss	fractions of seconds	(1/10 ; 1/100)
A	Status	(A = time data valid)	
		(V = time data not valid)	
bbbb.bb	latitude of receiver position in degrees		
	leading signs are replaced by a space character (20h)		
n	latitude, the following characters are possible:		
	'N'	north of equator	
	'S'	south d. equator	
lllll.ll	longitude of receiver position in degrees		
	leading signs are replaced by a space character (20h)		
e	longitude, the following characters are possible:		
	'E'	east of Greenwich	
	'W'	west of Greenwich	
ddmmyy	the current date:		
	dd	day of month	(01..31)
	mm	month	(01..12)
	yy	year of the century	(00..99)
a	magnetic variation		
hh	checksum (EXOR over all characters except '$' and '*')		
<CR>	Carriage Return, ASCII Code 0Dh		
<LF>	Line Feed, ASCII Code 0Ah		

11.1.5 Format of the Uni Erlangen String (NTP)

The time string Uni Erlangen (NTP) of a GPS clock is a sequence of 66 ASCII characters starting with the STX (start-of-text) character and ending with the ETX (end-of-text) character. The format is:

<STX>*tt.mm.jj; w; hh:mm:ss; voo:oo; acdfg i;bbb.bbbbn lll.llllе hhhhm*<ETX>

The letters printed in italics are replaced by ASCII numbers whereas the other characters are part of the time string. The groups of characters as defined below:

<STX>	Start-Of-Text, ASCII Code 02h sending with one bit occuracy at change of second		
dd.mm.yy	the current date:		
	dd	day of month	(01..31)
	mm	month	(01..12)
	yy	year of the century	(00..99)
	w	the day of the week	(1..7, 1 = Monday)
hh.mm.ss	the current time:		
	hh	hours	(00..23)
	mm	minutes	(00..59)
	ss	seconds	(00..59, or 60 while leap second)
v	sign of the offset of local timezone related to UTC		
oo:oo	offset of local timezone related to UTC in hours and minutes		
ac	clock status characters:		
	a:	'#'	clock has not synchronized after reset
	' '	(space, 20h) clock has synchronized after reset	
	c:	'*'	GPS receiver has not checked its position
	' '	(space, 20h) GPS receiver has determined its position	
d	time zone indicator:		
	'S'	MESZ	European Summertime, daylight saving enabled
	' '	MEZ	European Standard Time, daylight saving disabled
f	anouncement of discontinuity of time, enabled during last hour before discontinuity comes in effect:		
	'!'	announcement of start or end of daylight saving time	
	' '	(space, 20h) nothing announced	
g	anouncement of discontinuity of time, enabled during last hour before discontinuity comes in effect:		
	'A'	announcement of leap second insertion	
	' '	(space, 20h) nothing announced	
i	leap second insertion		
	'L'	leap second is actually inserted (active only in 60th sec.)	
	' '	(space, 20h) no leap second is inserted	
bbb.bbbb	latitude of receiver position in degrees leading signs are replaced by a space character (20h)		
n	latitude, the following characters are possible:		
	'N'	north of equator	

	'S'	south d. equator
lll.llll	longitude of receiver position in degrees leading signs are replaced by a space character (20h)	
e	longitude, the following characters are possible:	
	'E'	east of Greenwich
	'W'	west of Greenwich
hhhh	altitude above WGS84 ellipsoid in meters leading signs are replaced by a space character (20h)	
<ETX>	End-Of-Text, ASCII Code 03h	

11.1.6 Format of the ABB SPA Time String

The ABB SPA Time String is a sequence of 32 ASCII characters starting with the characters **">900WD"** and ending with the **<CR>** (Carriage Return) character. The format is:

>900WD:*yy-mm-tt_ hh.mm;ss.fff:cc*<CR>

The letters printed in italics are replaced by ASCII numbers whereas the other characters are part of the time string. The groups of characters as defined below:

yy-mm-tt	the current date:		
	yy	year of the century	(00..99)
	mm	month	(01..12)
	dd	day of month	(01..31)
	_	Space (ASCII code 20h)	
hh.mm;ss.fff	the current time:		
	hh	hours	(00..23)
	mm	minutes	(00..59)
	ss	seconds	(00..59, or 60 while leap second)
	fff	milliseconds	(000..999)
cc	Check sum. EXCLUSIVE-OR result of the previous characters, displayed as a HEX byte (2 ASCII characters 0..9 or A..F)		
<CR>	Carriage Return, ASCII Code 0Dh		

12 Skilled/Service-Personnel only: Replacing the Lithium Battery

The life time of the lithium battery on the board is at least 10 years. If the need arises to replace the battery, the following should be noted:

ATTENTION!

There is a Danger of explosion if the lithium battery is replaced incorrectly. Only identical batteries or batteries recommended by the manufacturer must be used for replacement.

The waste battery has to be disposed as proposed by the manufacturer of the battery.

13 CE-Label

Low-Voltage guideline

EN 60950-1
Safety of Information Technology Equipment,
including Electrical Business Equipment

Electromagnetic compatibility

EN50081-1
Electromagnetic compatibility (EMC).
Generic emission standard. Part 1: Residential, commercial and light industry

EN50082-2
Electromagnetic compatibility (EMC).
Generic immunity standard. Part 2: Industrial environment

Konformitätserklärung

Declaration of Conformity

Hersteller
Manufacturer

Meinberg Funkuhren GmbH & Co. KG
Lange Wand 9
D-31812 Bad Pyrmont

erklärt in alleiniger Verantwortung, daß das Produkt
declares under its sole responsibility, that the product

Produktbezeichnung — **PC Satellitenfunkuhr**
Product Name

Modell / Typ — **GPS180PEX**
Model Designation

auf das sich diese Erklärung bezieht, mit den folgenden Normen übereinstimmt
to which this declaration relates is in conformity with the following standards

EN55022:2008-05, Class B	Grenzwerte und Meßverfahren für Funkstörungen von informationstechnischen Einrichtungen Limits and methods of measurement of radio interference characteristics of information technology equipment
EN55024:2003-10	Grenzwerte und Meßverfahren für Störfestigkeit von informationstechnischen Einrichtungen Limits and methods of measurement of Immunity characteristics of information technology equipment

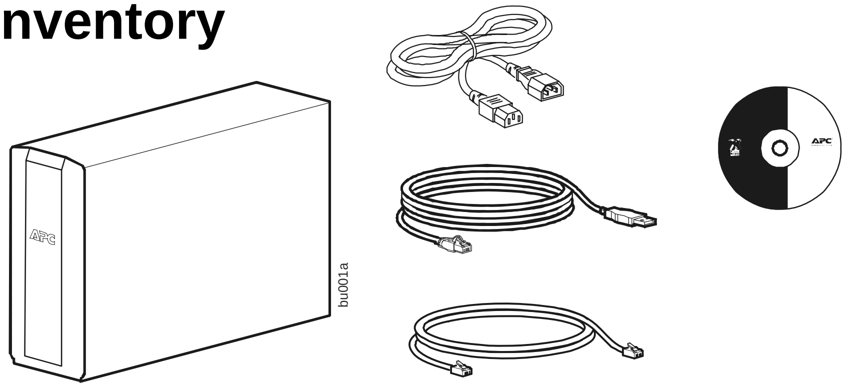
gemäß den Richtlinien 2004/108/EG (Elektromagnetische Verträglichkeit), 2006/95/EG (Niederspannungsrichtlinie) und 93/68/EWG (CE Kennzeichnung) sowie deren Ergänzungen.
following the provisions of the directives 2004/108/EC (electromagnetic compatibility), 2006/95/EC (low voltage directive) and 93/68/EEC (CE marking) and its amendments.

Bad Pyrmont, den 19.01.2011

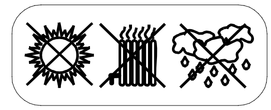
Günter Meinberg
Managing Director

Back-UPS® RS 550 Installation & Operation

Inventory



Safety



Do not install the UPS in direct sunlight, in excessive heat, humidity, or in contact with fluids.

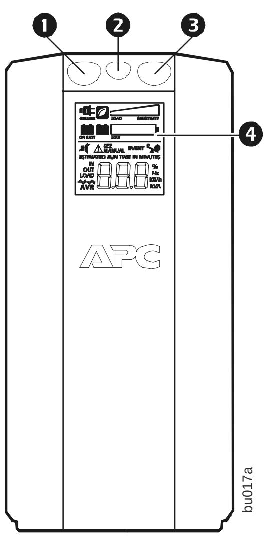
Do not connect a laser printer or hair dryer to the unit.

Ensure that the connected equipment does not exceed the maximum load.

Overview

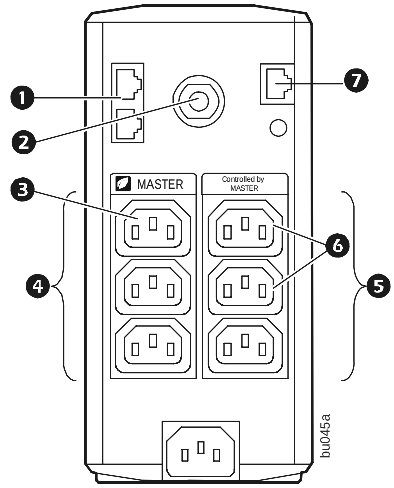
Front panel

❶ Mute
❷ Power On/Off
❸ Display/Menu
❹ Display interface



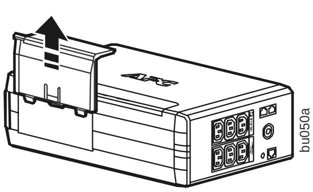
Rear Panel

❶ Ethernet ports
❷ Circuit breaker
❸ Master outlet
❹ Battery Back-UPS outlets
❺ Surge protected outlets
❻ Controlled outlets
❼ Data port

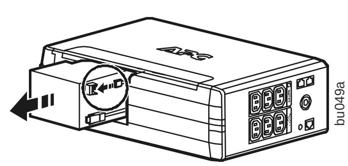


Connect the battery

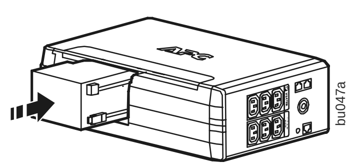
❶



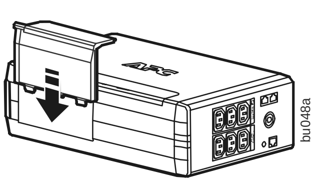
❷



❸



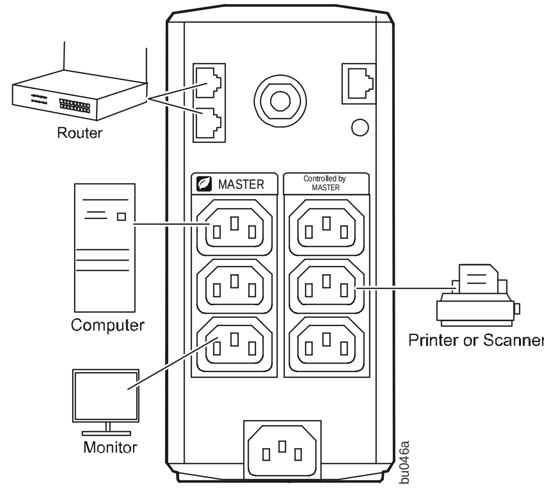
❹



❺ Charge the battery for at least 16 hours before use.

Connect the equipment

Connect the equipment



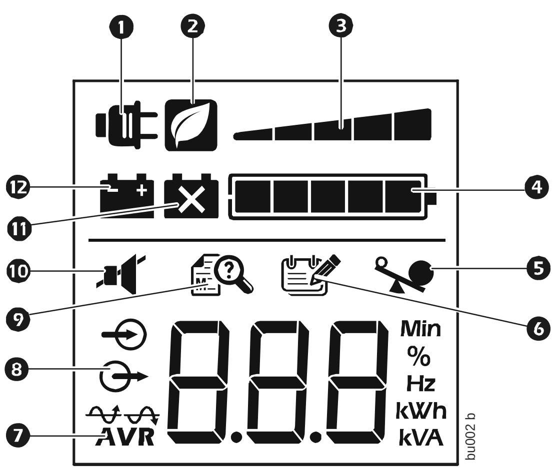
1. Connect equipment to the Battery Backup and Surge Protection outlets. When the Back-UPS is receiving AC power, these outlets will supply power to connected equipment. During a power outage or other utility problems, the Battery Backup outlets receive power for a limited time from the unit.
2. Use the AC power cord to connect the Back-UPS directly to a utility power outlet.
3. Connect a router or cable modem to the corresponding ports.

Install PowerChute® Personal Edition software

1. Connect the supplied USB software interface cable to the data port, and the other end to a computer with access to the internet.
2. Go to www.apc.com/tools/download.
3. Select **PowerChute Personal Edition**. Then select the appropriate operating system and follow the instructions to download the software.

Operation

Display interface



Description, if the icon is illuminated:

❶ **On Line—**The UPS is supplying utility power to connected equipment

❷ **Power-Saving—**Master and controlled outlets are enabled, saving power when the master device goes into sleep or standby mode

❸ **Load Capacity—**The load is indicated by the number of sections illuminated, one to five. If the load exceeds the rated capacity, the Overload symbol will flash off and on.

❹ **Battery Charge—**The battery charge level is indicated by the number of sections illuminated. When all five blocks are illuminated, the Back-UPS is at full charge. When one block is filled, the Back-UPS is near the end of its battery capacity, the indicator will flash and the unit will beep continuously.

❺ **Overload—**The power demand from the load has exceeded the capacity of the Back-UPS.

❻ **Event—**An event has occurred and the unit needs attention.

❼ **Automatic Voltage Regulation**—The unit is compensating for extremely low input voltage, but is not using battery power.

❽ **In—**Input voltage.
Out—Output voltage.

❾ **System Faults—**The system has a fault. The fault number will illuminate on the display interface. See “System Faults” on page 4.

❿ **Mute—**The audible alarm has been turned off.

⓫ **Replace Battery—**The battery is not connected or is nearing the end of its useful life. Replace the battery.

⓬ **On Battery—**The unit is supplying battery backup power to the connected equipment, it will beep four times every 30 seconds.

Modes of operation

Press DISPLAY to scroll through the display screens.

On Line Mode	On Battery Mode
Input Voltage	Estimated runtime in minutes
Counter	Power Event Counter
Estimated run time	Output Voltage
Load in Watts	Input Voltage
Load in %	Load in Watts
Output Voltage	Load in %
Output Frequency	Output Frequency

Other status indicators

AVR: The Automatic Voltage Regulation (AVR) feature will compensate for excessively low input voltages, without using battery power.When the AVR symbol is illuminated on the LCD, the unit is in Boost mode, using the AVR feature.

Configuration

Power-Saving Master and Controlled outlets

To conserve electricity, configure the Back-UPS to recognize a Master device, such as a desktop computer or an A/V receiver, and Controlled peripheral devices, such as a printer, speakers, or a scanner. When the Master device goes into Sleep or Standby mode, or turns OFF, the Controlled device(s) will shut down as well, saving electricity.

Enable the Power-Saving feature. Press and hold MUTE and DISPLAY simultaneously for two seconds. The unit will beep to indicate that the feature is enabled. The leaf icon on the display will illuminate.

Disable the Power-Saving feature. Press and hold MUTE and DISPLAY simultaneously for two seconds. The unit will beep to indicate that the feature is disabled. The leaf icon on the display will darken.

Setting the threshold. The amount of power used by a device in Sleep or Standby mode varies between devices. It may be necessary to adjust the threshold at which the Master outlet signals the Controlled outlets to shut down.

1. Ensure a master device is connected to the Master outlet. Put that device into Sleep or Standby mode, or turn it OFF.
2. Press DISPLAY and MUTE simultaneously and hold for six seconds, until the leaf icon flashes three times and the unit beeps three times.
3. The Back-UPS unit will now recognize the threshold level of the Master device and save it as the new threshold setting.

Power-Saving LCD Display

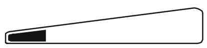
When unit power is On, the LCD may remain illuminated or be darkened for energy savings.

1. Full Time LCD Mode: Press and hold DISPLAY for two seconds. The LCD will illuminate and the unit will beep to confirm the Full-Time mode.
2. Power-Saving Mode: Press and hold DISPLAY for two seconds. The LCD will darken and the unit will beep to confirm the Power-Saving mode. While in Power-Saving Mode, the LCD will illuminate if a button is pressed, it then darkens after 60 seconds of no activity.

Unit sensitivity

Adjust the sensitivity of the UPS to control when it will switch to battery power; the higher the sensitivity, the more often the unit will switch to battery power.

1. Ensure the unit is connected to utility power, but is OFF.
2. Press and hold the POWER button for six seconds. The LOAD CAPACITY bar will flash on and off, indicating that the unit is in programming mode.
3. Press POWER again to rotate through the menu options. Stop at selected sensitivity. The unit will beep to confirm the selection.



Low sensitivity
156-288 Vac
Input voltage is extremely low or high. (Not recommended for computer loads.)

Medium sensitivity
176-282 Vac
The Back-UPS frequently switches to battery power.

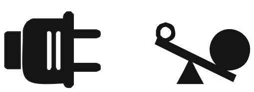
High sensitivity
176-276 Vac
The connected equipment is sensitive to voltage fluctuations.

Warnings and System Faults

Warnings

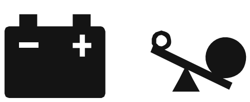
Press DISPLAY to scroll through the display screens.

Warning 1



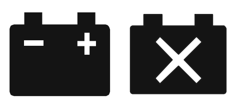
ON LINE overload condition, indicated by the illuminated ON LINE icon, and the flashing overload icon.

Warning 2



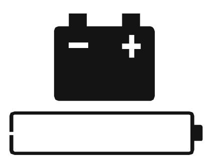
Backup battery (ON BATT) overload condition. This is indicated by the flashing overload icon.

Warning 3



In ON LINE mode, and there is a bad battery, indicated by the flashing icon.

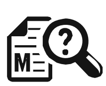
Warning 4



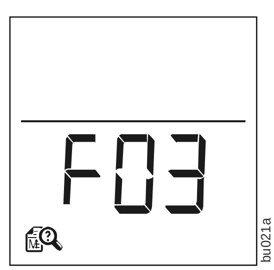
The battery charge is low, and the Battery Charge indicator bar is flashing.

System Faults

The unit will display the fault messages. Contact APC Technical Support for additional support.



- F01 - On-Battery Overload
- F02 - On-Battery Output Short
- F03 - On-Battery Xcap Overload
- F04 - Clamp Short
- F05 - Charge Fault
- F06 - Relay Welding
- F07 - Temperature
- F08 - Fan Fault
- F09 - Internal Fault



Function Button Quick-Reference

Function	Button	Timing (seconds)	UPS Status	Description
Power				
Power On		0.2	Off	Press POWER to start receiving input utility power. If A/C input power is not available, the unit will run on battery power.
Power Off		2	On	The unit is not receiving input utility power, but is providing surge protection.
Display				
Status Inquiry		0.2	On	Verify the status or condition of the unit. The LCD will illuminate for 60 seconds.
Full-Time/Power-Saving mode		2	On	The LCD will illuminate and the unit will beep to confirm the Full-Time mode. The LCD will darken and the unit will beep to confirm the Power-Saving mode. While in Power-Saving Mode, the LCD will illuminate if a button is pressed, then darkens after 60 seconds of no activity.
Mute				
Event Specific		0.2	On	Disable any audible alarms caused by an event.
General Status Enable/ Disable		2	On	Enable or disable the audible alarms. The Mute icon will illuminate and the unit will beep one time. The Mute function will not activate unless the UPS is operating on battery power.
Sensitivity		6	Off	The Load Capacity icon will blink, indicating that the unit is in programming mode. Use the POWER button to scroll through Low, Medium, and High, stop at selected sensitivity. The unit will beep to confirm selection. See Configuration for details.
Master/Controlled outlet Enable/Disable		2	On	The leaf icon will darken indicating that the Master Outlet feature is disabled or illuminate to indicate the Master Outlet feature is enabled. The unit will beep once.
Master/Enable Threshold Calibration		6	On	While calibrating the threshold setting, the device connected to the Master Outlet should be turned off or placed in Standby or Sleep mode. Upon completion, Power-Saving icon will flash 3 and beep 3 times.
Self-Test (manual)		6	On	The UPS will perform a test of the internal battery. Note: This will happen automatically when the unit is turned ON.
Event Reset		0.2	On	When the Event screen is visible, press and hold DISPLAY, then press POWER, to clear the utility failure event counter.
Fault Reset		2	Fault	After a fault has been identified, press POWER to remove the visual indication and return to standby status.

Troubleshooting

Problem	Possible Cause	Corrective Action
Back-UPS will not switch on.	The unit is not connected to utility power.	Ensure that the unit is securely connected to an AC outlet.
	The circuit breaker has been tripped.	Disconnect non-essential equipment from the unit. Reset the circuit breaker. Re-connect equipment one item at a time. If the circuit breaker is tripped again, disconnect the device that caused the trip.
	The internal battery is not connected.	Connect the battery.
	The utility input voltage is out of range.	Adjust the transfer voltage and sensitivity range.
The unit does not provide power during a utility power outage.	Ensure that essential equipment is **not** plugged into a SURGE ONLY outlet.	Disconnect equipment from the SURGE ONLY outlet and re-connect to a BATTERY BACKUP outlet.
The unit is operating on battery power, while connected to utility power.	The plug has partially pulled out of the wall outlet, the wall outlet is no longer receiving utility power, or the circuit breaker has been tripped.	Ensure that the plug is fully inserted into the wall outlet. Ensure that the wall outlet is receiving utility power by checking it with another device.
	The unit is performing an automatic self test.	No action is necessary.
	The utility input voltage is out of range, the frequency is out of range, or the waveform is distorted.	Adjust the transfer voltage and sensitivity range.
The unit does not provide the expected amount of backup time.	Battery Backup outlets may be fully or improperly loaded.	Disconnect non-essential equipment from the BATTERY BACKUP outlets and connect the equipment to SURGE ONLY outlets.
	The battery was recently discharged due to a power outage and has not fully recharged.	Charge the battery cartridge for 16 hours.
	The battery has reached the end of its useful life.	Replace the battery.
The REPLACE BATTERY **indicator is illuminated.**	The battery has reached the end of its useful life.	Replace the battery.
The OVERLOAD indicator is illuminated.	The equipment connected to the unit is drawing more power than the unit can provide.	Disconnect non-essential equipment from the BATTERY BACKUP outlets and connect the equipment to SURGE ONLY outlets.
The SYSTEM FAULT **indicator is illuminated, all the front panel indicators are flashing.**	There is an internal fault.	Determine which internal fault message is displayed by matching the number displayed on the LCD with the corresponding Fault Message (see System Faults) and contact APC Technical Support.
Power is not supplied to some outlets.	Power to the Controlled Outlets has intentionally been turned off.	Confirm that the correct peripherals are connected to Controlled Outlets. If this feature is not desired, disable the Power-Saving Master and Controlled Outlets.
The Controlled Outlets are not supplying power, even though the Master device is not in sleep mode.	The Master Outlet threshold may be incorrectly set.	Adjust the threshold when the Master outlet signals the Controlled Outlets to shut down.

Specifications

VA	550 VA
Maximum Load	330 W
Nominal Input Voltage	230 V
Online Input Voltage Range	176 - 282 V
Frequency Range	50/60 Hz ± 1 Hz
On-battery Waveshape	Step-approximated sine-wave
Typical Recharge Time	12 hours
Transfer Time	8 ms, maximum
Operating Temperature	32° to 104°F (0° to 40°C)
Storage Temperature	23° to 113°F (-5° to 45°C)
Unit Weight	14.8 lbs (6.7 kg)
Interface	USB
EMI Classification	CE, C-Tick, KETI
Approvals	CE, TUV-GS, GOST, A-Tick, KETI, TISI

APC Worldwide Customer Support

Technical Support	http://www.apc.com/support
Internet	http://www.apc.com
Worldwide	+1 800 555 2725

Service

If the Back-UPS arrived damaged, notify the carrier.

If the Back-UPS requires service, do not return it to the dealer.

1. Consult the Troubleshooting section to eliminate common problems.
2. If the problem persists, go to http://www.apc.com/support/.
3. If the problem still persists, contact APC Technical Support. Have the Back-UPS model number, serial number and date of purchase available. Be prepared to troubleshoot the problem with an APC Technical Support representative. If this is not successful, APC will issue a Return Merchandise Authorization (RMA) number and a shipping address.

Warranty

The standard warranty is three (3) years from the date of purchase in the European Community. For all other regions, the standard warranty is two (2) years from the date of purchase. The APC standard procedure is to replace the original unit with a factory reconditioned unit. Customers who must have the original unit back due to the assignment of asset tags and set depreciation schedules must declare such a need at first contact with an APC Technical Support representative. APC will ship the replacement unit once the defective unit has been received by the repair department, or cross-ship upon the receipt of a valid credit card number. The customer pays for shipping the unit to APC. APC pays ground freight transportation costs to ship the replacement unit to the customer.

Customer support and warranty information is available at the APC Web site, **www.apc.com**.

990-3591
06/2009

Annexe 7

Liste matériel

Jérôme Lovey, TD - 2012

A disposition:		
PC	1pc	
Ecran	1pc	
Clavier	1pc	
souris	1pc	
UPS	1pc	
Antenne GPS	1pc	
Carte GPS 180PEX	1pc	
P-TRON	1pc	
Câble RG58 2m (avec fiches HF)	1pc	
Câble RG58 20m (avec fiches)	1pc	
Câble RG58 100m	1pc	
Fiche coaxiale standard à sertir	1pc	
Fiche coaxiale HF à sertir	1pc	
Switch 5 ports	1pc	
Fiche RS232 femelle à souder	1pc	
EFM-100	1pc	(Commandé mais pas encore reçu)
Trépied	1pc	

Manquant:		
Rallonge 230V	1pc	A adapter pour mettre à terre le moulin
Câbles patch	2pc	Relier PC au switch et au serveur

(A disposition au service informatique)