Project SIMONE (Solar & Ionospheric - MOnitoring NEtwork)
at the Ernst-Moritz-Arndt-Gymnasium (High school) at Bergen/Rügen (Germany)

by Karl-Heinz Eckelt, teacher for mathematics and physics and tutor of the students project

last edited by Volker Bothmer and Barbara Bernert on August 26, 2008

The project

Based on the initiative of Dr. Volker Bothmer from the Institute of Astrophysics at the University of Göttingen and Dr. Norbert Jakowski from the Institute of Telecommunication and Navigation of the German Space Agency DLR at Neustrelitz, several High Schools in northern Germany (in Hamburg, Niedersachsen, Mecklenburg-Vorpommern, see http://www.ieap.uni-kiel.de/et/ag-heber/ihy2007/aktivitaeten/simone/) participate in the national project SIMONE. SIMONE was initiated in the framework of the United Nation's world-wide International Heliophysical Year (IHY) Campaign in collaboration with the Solar Physics Group of Dr. Deborah Scherrer at the University of Stanford, USA, as lead institution (http://sid.stanford.edu/). To accomplish the project, the schools construct the required low frequency radio wave antennas, set up the connection of a radio wave monitor (Sudden Ionospheric Disturbance Monitor SID) to a PC, install the required software packages and transfer the measured data to the world data center at Stanford University and to our national data center at DLR Neustrelitz. Reference monitors are operated at University Göttingen and at DLR Neustrelitz.

Fig. 1: Neustrelitz, start of the project April 2007
(1st f.r. K.-H. Eckelt, 5th f. r. Dr. N. Jakowski)

Fig. 2: Our antenna in the school's garret
f.l. B. Diemer, T. Hermes, S. Bemowsky, M. Kröger)

Since May 2007 we received with the SID monitor, which was specifically produced by the University of Stanford and funded by the the German Space Company EADS/Astrium Friedrichshafen and the Institute of Astrophysics at the University of Göttingen, the continuously broadcasted radio wave signal at the frequency of 24 kHz of the US transmitter Cutler (Maine/USA). The transmitter is located 5,588 km (3,472.22 miles) away from our antenna station in Germany.

Every five seconds the signal is recorded and stored in a special Excel File which will be analyzed and displayed graphically. The daily data files are transferred on a routine basis to the data archive at Stanford University where graphs of all receiving stations world-wide are published at the website: http://sid.stanford.edu/database-browser/. You will find our station under 'EMAG' (Ernst-Moritz-Arndt-Gymnasium; S-0087-FB-0087).

What we measured

To first order, very low frequency radio wave propagation can be understood as a two component system. A ground wave propagate away from the transmitter and diffusing with distance and a sky wave reflected by the ionosphere after some distance from the transmitter. With a power of 1000 kW Cutler is one of the most powerful low frequency transmitters in the world. In the case of those powerful transmitters strong interferences between ground and sky waves emerge at certain distances from the transmitter. Therefore the received signal strength (measured in Volt) can fluctuate and is strongly affected by day and night and seasonal variations. These variations are clearly evident in the daily SID measurements at EMAG where a stable coherence of the signal and roughly constant radio wave amplitude appears only after sunrise.

Figure 1: Characteristic EMAD daily SID radio wave amplitude variation during May to August showing 3 distinct minima in the early morning.

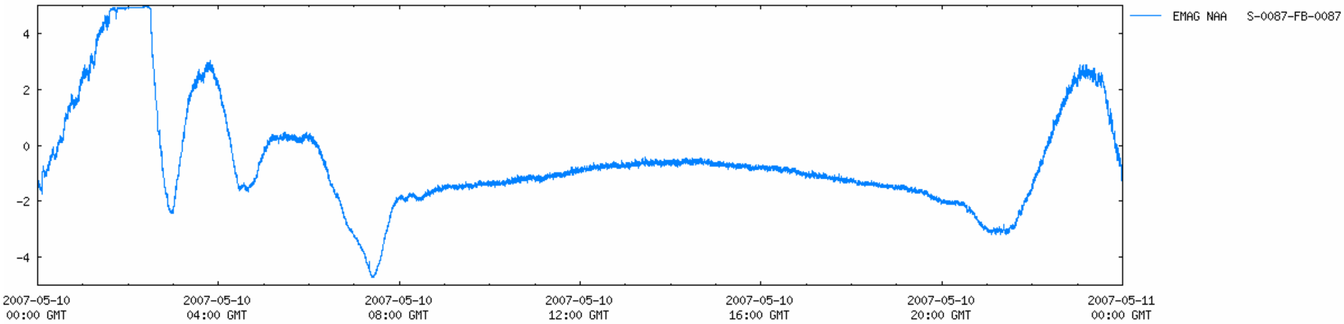
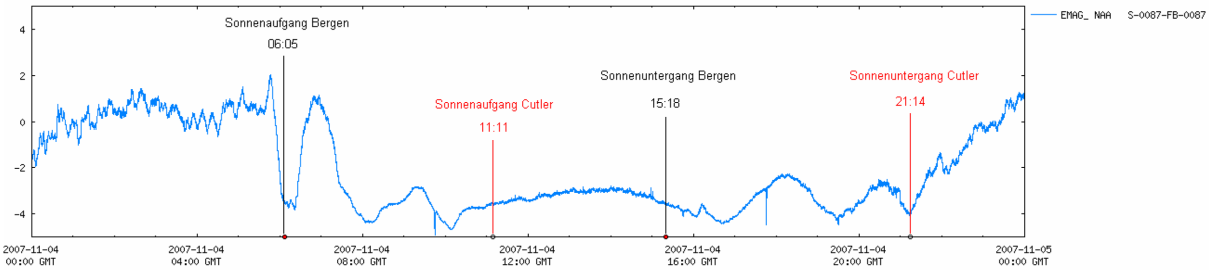


Figure 2: Daily SID signal variation in November, showing 3 distinct minima in the morning and in the evening. The red solid lines denote the times of sunrise and sunset at the transmitter station at Cutler, USA. The black lines those at EMAG.



The basic variation seen in the slope of the radio wave signal in the two graphs is in agreement with the time duration between sunrise at Cutler (Maine) and sunrise at Bergen/Rügen. It varies between 2 to 2,5 hours in December and 11 hours in June.

The first minima in the morning are temporally well coincident with the sunrise at Bergen. The third distinctive minimum in the evening shows a good agreement to the sunset time at Cutler. Here, seasonal variations appear also.

Since the plasma electron density, especially in the bottom part of the ionospheric D-layer, is most sensitive to extreme ultra violet radiation and x-rays which are sporadically emitted at times of solar eruptive processes, they can be picked up with the SID and identified in the SID measurements. The ionospheric changes lead to an enhanced propagation of the reflected sky wave known as a SID (Sudden Ionospheric Disturbance) effect, also known as Mögel-Dellinger effect. Note that such events will occur simultaneously at the dayside located monitors.

Figure 3: A SID effect simultaneously recorded at EMAG and at DLR Neustrelitz.

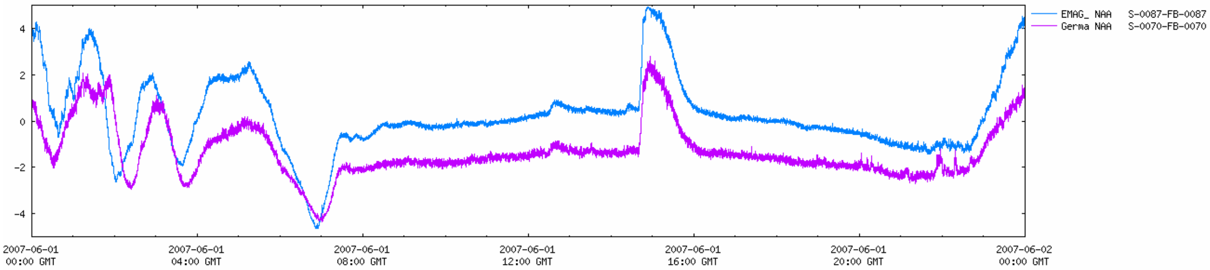


Table 1: 2007 Jun 01 X-ray flare events recorded by the US GOES 11 weather satellite:

#Event	Begin	Max	End	Obs	Q	Type	Loc/Frq	Particulars		Reg#
1380 +	12:24	12:35	12:50	G11	5	XRA	1-8A	B6.9	7.8E-04	0960
1400 +	14:17	14:22	14:27	G11	5	XRA	1-8A	B6.6	2.5E-04	0960
1410 +	14:35	14:59	15:11	G11	5	XRA	1-8A	M2.8	2.9E-02	0960

On June 1, 2007, the radio signal was rapidly increasing from 2:35 pm (Universal Time, UT) until 2:59 UT pm when it reached its peak intensity in analogy to the duration of a major sporadic X-ray emission (a solar X-ray flare), a so called M-class flare, as recorded by GOES 11. Note that less intense flares, e.g., at 12:45 pm to 12:50 pm, can be uniquely identified as smaller peaks in both graphs.

The solar flares are often associated with large ejections of coronal matter known as coronal mass ejections (CMEs). CMEs are huge clouds of plasma and magnetic field emitted ibnto interplanetary space. They are the prime triggers of space weather events. With speeds of several hundred km/s to 2000 km/s they can hit the Earth one to four days later. Detection of solar flare/CME events with the SID monitors is possible only for larger solar events at dayside located stations.

EM Interferences in the SID data

Figure 4: A natural cause of EM interferences in the SID data are thunderstorms frequently seen during the summer time.

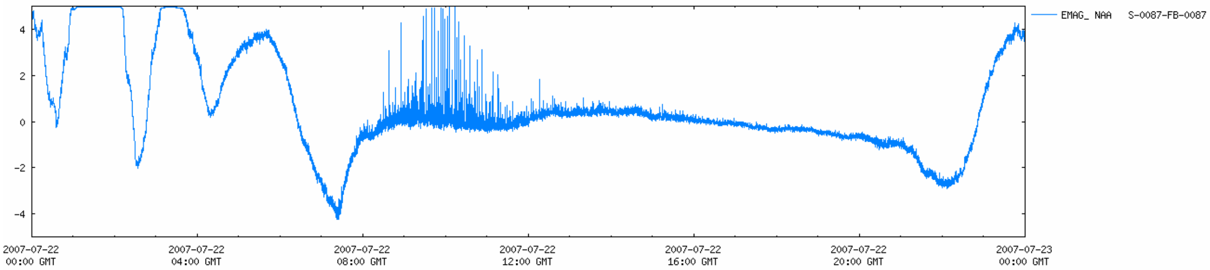
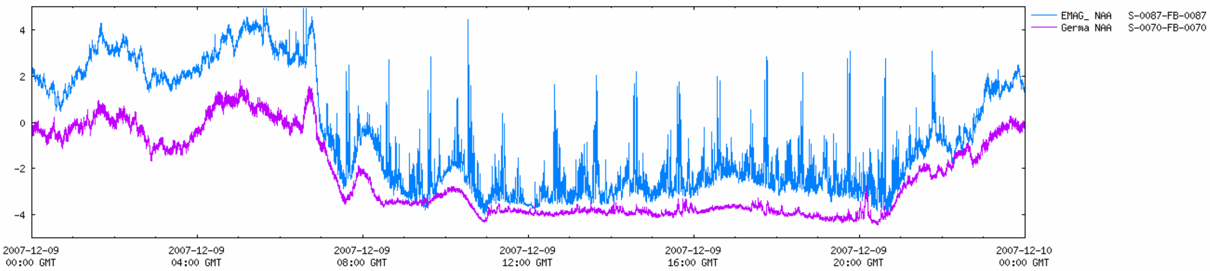


Figure 5: Artificial EM interferences caused by a EM source located in the immediate vicinity of EMAG occurred on 5th of November 2007 and have been detected the following week on.



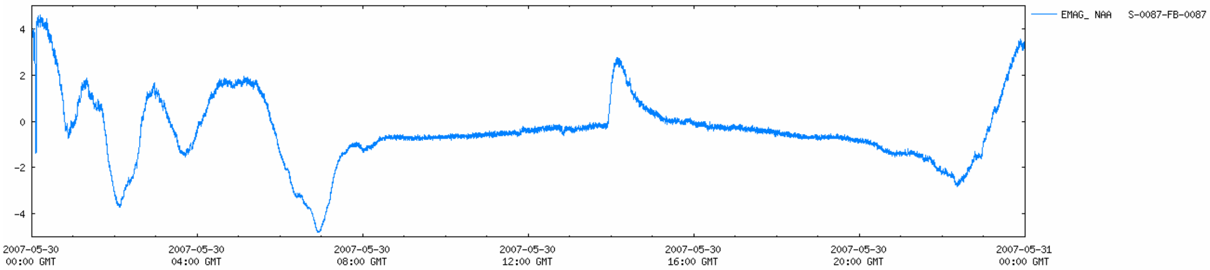
Obviously the EM peaks apparent on fifth of November occurred periodically during the day. Also in Neustrelitz - pink curve - slight interferences of the signal could be observed.

We achieved a decoupling of the disturbing signal after rotating the antenna by 90 degree (on the recommendation of the Bundesnetzagentur (Federal Network Agency)). The nature of the disturbing source still needs to be identified.

Do flares also influence photovoltaic solar power plants?

In coincidence with some X-ray flares in May 2007 we noticed an increase in the power of our photovoltaic plant and started a careful inspection of the SID and power plant measurements, an aspect not scientifically analyzed in detail to our knowledge yet.

Figure 6: Flare and SID effect on 30th May 2007.



The X-rays lead to enhanced ionization levels of the dayside ionosphere. We will further investigate which other effects of the X-ray flare can cause the increase in the output of the photovoltaic module at the ground. We know that during flares EM radiation are emitted over a wide fraction of the EM spectrum, ranging from radio to gamma ray waves. A coincidence was noticed so far more than 26 times during larger X-ray flares in the period May to August 2007.

In Karnitz on the Isle of Rügen there is a bigger Photovoltaic solar power plant with 91,43 kWp, whose averaged data are gathered every 15 minutes. These data may be used for our investigations. Further, the solar cell module manufacturer SHARP kindly provided excess to some data from their testing site at Kassel (Germany). An extract of the data from May 30th 2007 is shown in Table 2.

Table 2:Data of Kassel and Karnitz (Germany)

Begin	Max	End Obs Q	Type Loc/Frq	Particulars	PV Power Plant		
1:49pm	2:15pm	2:54pm G11 5	XRA 1-8A	C2.0 5.9E-03	**Kassel, Karnitz**		
Kassel Time (UT)	Global Irradiation W/m^2	Direct Irraditaion W/m^2	Global 30° W/m^2	Cristalline Module, sloped 30°			
				Spannung in V	Strom in A	Leistung in W	
1:50pm	505,58	211,82	511,12	21,03	3,490	73,40	
2:00 pm	706,98	217,05	728,02	20,89	4,992	104,31	
2:10 pm	651,52	204,47	663,35	20,55	4,533	93,17	
2:20 pm	665,73	172,12	675,22	21,06	4,718	99,38	
2:30 pm	518,23	146,98	523,89	20,94	3,582	75,00	
Karnitz	Output in W	Mpp Voltage in V	Increase of Output	Increase in kWh			
1:45 pm	37051	591,1		9,2			
2:00 pm	44199	581,5	present	11,1			
2:15 pm	44149	582,4	present	11,0			
2:30 pm	39540	576,3		9,9			
2:45 pm	32167	583,6		8,0			

(The information in the upper row is from the American weather satellite GOES 11).

Table 2 shows that during the flare on May 30, 2007, simultaneous increases of the PV modules output were recorded at Kassel and Karnitz/Rügen.

A rough estimate yields an increase at the order of 1% output at days with solar flares.

Attempt to analyze the phenomenon

Auroral lights emerge when electrons, which have been accelerated to energies in the keV range through instabilities in the tail of the earth's magnetosphere, hit the upper layer o f the earth's atmosphere. There, they activate air O,N molecules to emit at specific wavelengths. Green and red light emerge from emission of oxygen atoms in different energy states. Energized nitrogen atoms emit violet and blue light. Note that to stimulate nitrogen atoms, higher energies are needed. Similar effects may occur through the additionally produced EUV and X-ray radiation during a flare.