The Largest Ionospheric Disturbances Produced by the HAARP HF Facility

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HAARP Disturbances

• Ionospheric Modification Physics
• Artificial Ionization
  – Associated Stimulated Electromagnetic Emissions
  – Largest Artificial Density Below Natural Ionosphere
  – Use of Twisted Beam to Form Stable Ionization
  – Longest Duration Plasma Cloud
• VHF/UHF Scintillations
  – Historical Results
  – Strongest SATCOM Scintillations
  – Role of Artificial Ionization
• Implications of Artificial Disturbances
Ionospheric Modification with High Power Radio Waves

High Power Electromagnetic Wave Beam

Electron Temperature Elevation

Plasma Pressure and Density Changes

VLF Ducts and Conductivity Modification

VLF Waveguides and VLF Generation

Plasma Irregularity Formation

Enhanced Radar Scatter

Enhanced UHF/L-Band Scintillations

Parametric Decay and Strong Turbulence

Low Frequency Waves

Mode Conversion

Stimulated Electromagnetic Emissions

Electrostatic Wave Generation

High Frequency Waves

Electron Acceleration

Artificial Aurora and Ionization

High Power Electromagnetic Wave Beam

High Frequency Waves

Electrostatic Wave Generation

Low Frequency Waves

Parametric Decay and Strong Turbulence

Ion Line

Plasma Line

Enhanced UHF/L-Band Scintillations

Enhanced Radar Scatter

VLF Ducts and Conductivity Modification

VLF Waveguides and VLF Generation

Plasma Pressure and Density Changes

Electron Temperature Elevation

Plasma Irregularity Formation

High Power Electromagnetic Wave Beam
Artificial Ionization Cloud Formed Around 4.325 MHz
SEE and AI Observed during 3rd $f_{ce}$ Frequency Sweep

Date: 05/01/2012  Start Time (UTC): 05:29:40

Plasma Cloud Formation at 3rd Gyro Harmonic

Downshifted Emission

Cloud Peak

BUM

DWISP  UWISP

DBlob

Relative Power (dBC)

-120

Altitude (km)

$ f $ (MHz)

Frequency Offset (kHz) From 4.325 MHz
2nd, 3rd, 4th, and 6th Harmonic Artificial Plasma Clouds Near Multiples of 1.44 MHz Electron Gyro Frequency
Simulations of Plane EM Wave Interactions with Plasma Plate and Ring

3 MHz Pump
0.9 km Diameter Cloud

Plasma Plate

Plasma Ring

|E| (V/m)

Enhanced Fields and Al on Bottom

Focused Fields and Al on Axis
14 March 2013 01:00 to 01:20 GMT
Extended Artificial Ionization with 5.8 MHz Twisted Beam

Al with $14^\circ$
Magnetic Zenith
Pencil Beam

Al with $7^\circ$
Intermediate Zenith
Twisted Beam
14 March 2013 01:30 to 04:00 GMT
Extended Artificial Ionization
with 5.8 MHz Twisted Beam

HAARP 14 Mar 2013, 01:30 GMT
HAARP 14 Mar 2013, 01:56 GMT
HAARP 14 Mar 2013, 02:30 GMT
HAARP 14 Mar 2013, 03:00 GMT
HAARP 14 Mar 2013, 03:30 GMT
HAARP 14 Mar 2013, 04:05 GMT

½ Hour 1 Hour 1 ½ Hour 2 Hours 2 ½ Hour 3 Hours
Underwhelming UHF Scintillations Produced by EISCAT Heating in Norway

**Figure 1.** Illustrates the geometry of the observations using the EISCAT heater. The shaded region indicates the half-power beam circle of the heater along with the locus of the intersection of the propagation path from the polar beacon satellite to the receiver at Grunnfjord with the HF reflection altitude of 250 km. The inset diagram shows the growth and decay of scintillations at 250 MHz during the heater "on" and "off" cycles.

\[ S_4 = \frac{\sqrt{\langle I^2 \rangle} - \langle I \rangle^2}{\langle I \rangle} = 0.11 \]
Weak Scintillations at 150 and 400 MHz Produced by HAARP Heating in Alaska
Secan et al. AFRL Report AFRL-VS-HA-TR-2008-1139

Amplitude Scintillation Index

\[ S_4 = \frac{\sqrt{\langle I^2 \rangle - \langle I \rangle^2}}{\langle I \rangle} \]

Detrended VHF (top panel), UHF (middle panel), and differential phase (lower panel) from a 200-second segment of data collected at Gakona, AK, from the Oscar 25 pass at 0033 UT on 27 March 2006. The vertical dashed line indicates the time of closest approach to the field-aligned point (as observed from Gakona), and the horizontal dashed lines indicate the time during which the ray path was within 8° of beam-center (the region within which heater-generated optical emissions are typically observed).
COMMEX Working with HAARP

TacSat-4 Actively Pointed to Ground Receiver

Strong VHF Scintillations

F-Layer Ionosphere

Modified Region

High Power HF

HAARP

Ground Receiver

TACsat4 Zenith (Degrees)

Relative Power Range (dB)
14 March 2012 TACSat4 253 MHz Scintillations
4th (5.8 MHz) Gyro Harmonic HF Continuous Twisted Beam

Moderate Scintillation

Weak Scintillation
Radio Propagation CubeSat: PROPCUBE

- **PROPCUBE**
  - 380 to 400 MHz UHF Band
  - 2340 to 2380 MHz S-Band
  - Frequency Pairs: (2340/390) = (2346/391) = (2352/392) ... (2376/396) = 6

- **Launch Schedules**
  - 13 July 2015 (PROPCUBE-2 Fauna) 51.6 Degree Inclination Space-X
  - 27 September 2015 (PROCUBE-1 Flora and PROPCUBE-3 Meriwether) 63 Degree Inclination for HAARP

- **Ionospheric Electron Density and Irregularities**
  - Total Electron Content by Differential Group Delay
  - Plasma Irregularities by Amplitude and Phase Scintillations
  - Detection of Artificial Ionization/Irregularities Generated by HAARP, Arecibo, SURA
Artificial Ionization Clouds in Near-Earth Space

- **Goal**: Understand the Physics for RF Generation of Artificial Plasma Clouds in the Upper Atmosphere
- **Current Artificial Ionization (AI) Technique**
  - High Power Radio Waves Tuned to Electron Gyro Frequency Harmonics
  - Single Mode “Pencil Beam” on the Bottomside Ionosphere
  - Limited Duration and Stability of Artificial Ionization Clouds
- **Improved AI Technique Developed by NRL**
  - Employ “Twisted Beam” of High Power RF
  - Tune to 2nd, 3rd, 4th, 5th or 6th Electron Cyclotron Harmonic at Selected Altitude
  - Decrease Breakdown Power Requirements with Seed Ionization Clouds
- **Theoretical Support of Concept**
  - Electromagnetic Models of Pump Wave Propagation and Electrostatic Wave Generation
  - Electron Acceleration Model Leading to Enhanced Ionization
  - Full Wave Simulations of HF Wave Self-Action with AI Clouds
- **Experimental Support of Concept**
  - Demonstration of Long Duration AI Cloud Using HAARP in Alaska
- **Localized Control of Ionospheric Propagation by AI**
  - New HF Reflection Layers Below 200 km Altitude
  - Enhanced Plasma Irregularity Turbulence that Distorts Trans-Ionospheric Radio Signals