# Up in smoke … destructive interference

Harvey Liszt
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# Destructive & Disruptive Interference

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# An emerging issue

- Radio systems for voice/data were not generally of concern, even when they have stronger emissions
    - A cell phone emits more power than a car radar
- Radiolocation and radionavigation systems (radar) are of such concern
    - They typically use much higher power
    - Some w/ low power operate at high frequency, perhaps in proximity to the telescope

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# The basics

- As summarized in ITU-R Report RA.2188 it takes ~ 5-35 mW input power to burn out a modern RAS receiver
  - 1 V across 50 ohm, what could be simpler?
  - SiS junction or transistor amplifier ~ same
- There's much we don't know but it seems to happen quickly, depends only on wattage
  - Some tests done for defense in 1980's
  - The most sensitive devices had more problems at high signal levels, development was stopped

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# The basics RA. 2188

- Destructive mW for transistor amplifiers

TABLE 1

**Representative antenna diameters and values of $F_d$, the potentially damaging pfd for HFET input stages from 1-90 GHz**

| Frequency (GHz) | RA antenna diameter (m) | RA antenna effective area ($m^2$) | $P_d$ (mW) | $F_d$ (dB(W/$m^2$)) | e.i.r.p.$_d$ at 400 km (dBW) |
|---|---|---|---|---|---|
| 1-20 | 25 | 344 | 15 | –43 | 80 |
| 1-20 | 100 | 5 500 | 15 | –55 | 68 |
| 20-50 | 25 | 344 | 10 | –45 | 78 |
| 20-50 | 100 | 5 500 | 10 | –57 | 66 |
| 50-90 | 25 | 344 | 5 | –48 | 75 |
| 50-90 | 100 | 5 500 | 5 | –60 | 63 |

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TABLE 2

**Representative values of $F_d$, the potentially damaging pfd for SIS mixer receivers at 90-275 GHz, for representative radio astronomy sites**

| Observatory[1] | Junction area $(\mu m)^2$ | Number of junctions | Antenna diameter (m) | Antenna effective area ($m^2$) | $P_d$ (mW) | $F_d$ (dB(W/$m^2$)) | e.i.r.p.$_d$ at 400 km (dBW) |
|---|---|---|---|---|---|---|---|
| ALMA | 3.8 | 8 | 12 | 79.2 | 55 | –32 | 91 |
| CARMA 6 m | 1.21 | 1 | 6 | 19.8 | 4 | –37 | 86 |
| CARMA 6 m | 2.24 | 1 | 6 | 19.8 | 5 | –36 | 87 |
| CARMA 10 m | 1.44 | 2 | 10 | 55.0 | 9 | –38 | 85 |
| CARMA 10 m | 3.8 | 4 | 10 | 55.0 | 27 | –33 | 90 |
| IRAM Bure | 4.0 | 2 | 15 | 124 | 14 | –40 | 83 |
| IRAM Veleta | 2.25 | 6 | 30 | 495 | 32 | –42 | 81 |
| IRAM Veleta | 1.44 | 4 | 30 | 495 | 17 | –45 | 78 |
| Kitt Peak | 8.55 | 6 | 12 | 79.2 | 62 | –31 | 92 |
| Onsala | 4.01 | 2 | 20.1 | 222 | 14 | –42 | 81 |

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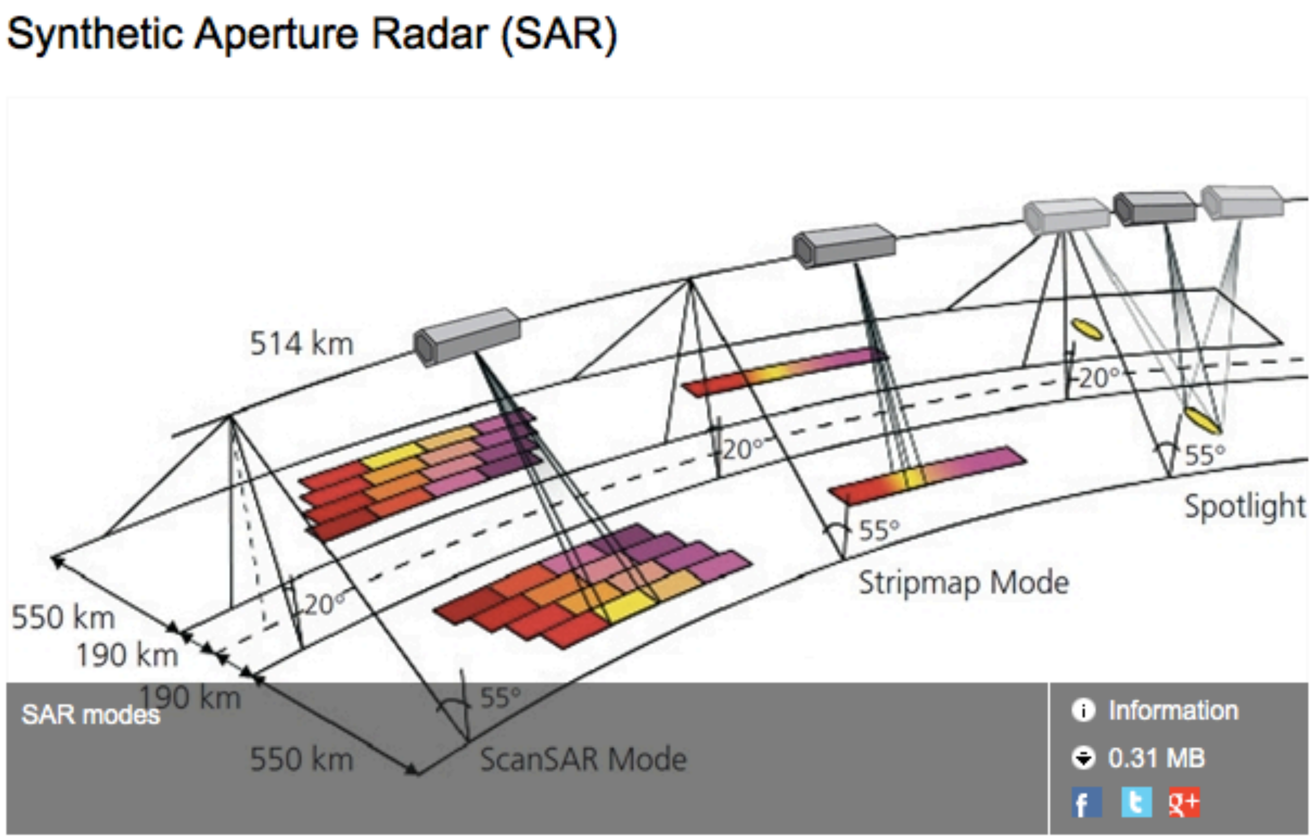
# Something of a surprise

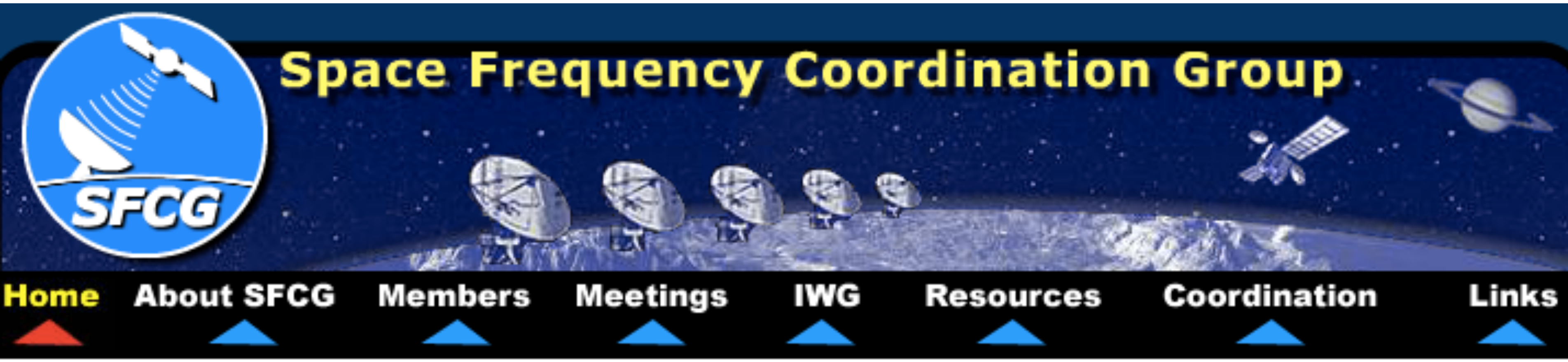
- The authors of RA. 2188 originally thought transistor amplifiers were more resistant

# Orbiting EESS(active) SAR

## All SAR capable of damaging receivers on 25m – 100m telescopes



https://www.sfcgonline.org




## Active Sensor Information for Radio Astronomers

At SFCG-30, the SFCG agreed to assist radio astronomers in protecting their sensitive receivers from damaging interference from spaceborne radars used for Earth observation and remote sensing by providing useful links and related information.

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## Active Sensors Look-Up Table

| Currently Operational Spaceborne Active Sensor Missions (Updated: June 2011) | | | | |
|---|---|---|---|---|
| **Mission** | **Agency** | **ITU Name** | **Frequency (MHz)** | **Radiated Power (W)** |
| Aquarius Scatterometer | NASA | AQUARIUS | 1260 | 200 |
| ERS-2 SAR/WS /RA[1] | ESA | ERS-1 | 5300/5300/13800 | 4800/4000/134 |
| RADARSAT-1/2 SAR | CSA | RADARSAT-1A RADARSAT-2C RADARSAT-2D RADARSAT-2E RADARSAT-2F | 5300 | 5000 |
| ENVISAT ASAR/RA-2 | ESA | ENVISAT | 5300/13575, 3200 | 4800/114, 65 |
| COSMO-SkyMed | ASI | COSMO SKYMED | 9600 | 2800 |
| TerraSAR-X SAR | DLR | TERRASAR | 9650 | 2260 |

This table is also available in MS-Word format. Additional information on Envisat and Metop sensors is also available. At SFCG-31, document SF31-9DR1 on "Potential Damage to RAS Sites by EESS (active) Systems" was presented by NASA providing calculations of the power levels received vis-à-vis power levels given in Report ITU-R RA.2188.

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Table 8 – Comparison of Typical Power Flux Density Levels at Earth's Surface with RAS Threshold Values

| Parameter | Sensor type | | | | |
|---|---|---|---|---|---|
| | **SAR** | **Altimeter** | **Scatterometer** | **Precipitation radars** | **Cloud profile radars** |
| Radiated power (W) | 4400 | 20 | 4000 | 1013 | 1500 |
| Antenna gain (dB) | 36.4 | 43.3 | 34 | 47.7 | 63.4 |
| Orbital altiude (km) | 225 | 1 336 | 785 | 400 | 705 |
| Incidence Angle (deg) | 21 | 0 | 32 | 0 | 0 |
| PFD (dB(W/m$^2$)) | -45.8 | -77.2 | -50.4 | -45.3 | -32.7 |
| RAS Threshold (dB(W/m$^2$)) | -60 | -60 | -60 | -60 | -45 |
| Margin (dB) | -14.2 | +17.2 | -9.6 | -14.7 | -12.3 |

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# Coda

Lesser but permanent damage can be inflicted by substantially lower input power but quantifying this is impractical

# Why higher frequency is worse

for terrestrial interferers

Cell phones radiate more power than car radars by far (factor 10) but cell phone emission is isotropic and has low flux

MM-wave portable devices emit less power but have narrow beams and higher *eirp*

It is much easier to focus all the transmitted power onto the surface of an RAS dish

*or a stray sidelobe*

# How near can car radar be allowed?

| Parameter | Radar A[1] Automotive radar For front applications for e.g. for adaptive cruise control | Radar B Automotive high-resolution radar For front applications |
|---|---|---|
| Sub-band used (GHz) | 76-77 | 77-81 |
| Typical operating range (m) | Up to 250 | Up to 100 |
| Range resolution (cm)<br>Maximum e.i.r.p. (dBm) | 75<br>55 | 7.5<br>33 |
| Maximum transmit power to antenna (dBm) | 10 | 10 |
| Antenna Azimuth Scan Angle (degrees) | TX / RX: ± 15 | TX: ± 22.5<br>RX: ± 25 |
| Antenna Elevation HPBW (degrees) | TX / RX: ± 3 | TX / RX: ± 5.5 |

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# How near can car radar be allowed?

For 76 GHz radar HPBW = $6^o$ = 0.1 radian

So an antenna fills the radar beam at

distance = 10 antenna diameters

For 100m telescope, 1 km

For 30m telescope, 300 m

For ALMA, 120m

# How near can car radar be allowed?-II

Detectors will not work properly in the presence of high signal levels

This is what caused DARPA to stop developing the most sensitive amplifiers

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# How near can car radar be allowed?-II

A car radar with eirp = 55 (33) dBm, received with 0 dBi gain will produce an input power of 0.1 nW at a distance of 560 (45) m

SiS junctions suffer 1% gain compression at input power of 0.2 nW (ALMA memo 401) and subtle intermodulation products at 0.1 nW according to NRAO

# How near can any radar be allowed?

How does 0.1nW = $10^{-10}$ W compare with the receiver noise power?

kTB = $1.6 \times 10^{-23} * 15 * 16 \times 10^{9} = 4 \times 10^{-12}$ W

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## Only factor 25 difference

# How near can car radar be allowed?-II

Conclusion: car radars begin to disrupt radio astronomy receivers at the same distances where they could destroy them

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Our receivers are functioning in a disruptive environment with continuous jamming

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The ratio between 1 W and 0.1 nW is much greater than any antenna gain

Our receivers are functioning in a battle-field environment with continual disruption

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Orbiting radars can put 1 W across a dish

The ratio between 1 W and 0.1 nW is much greater than any antenna gain

Created by "friendly fire" from other science services