Update on the Golden Ears Project

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HamSCI 2020
~~Scranton, Pennsylvania~~ Montclair, New Jersey (via video link)
March 20, 2020

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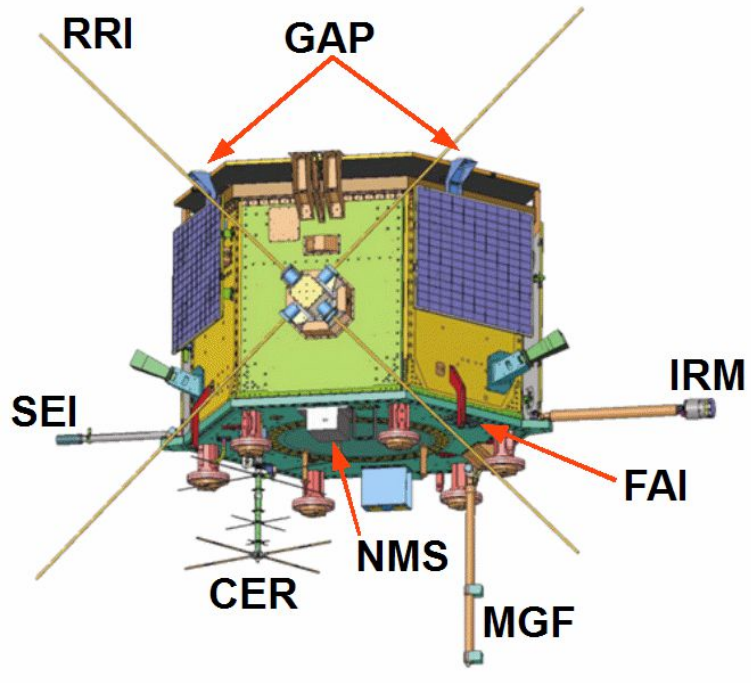
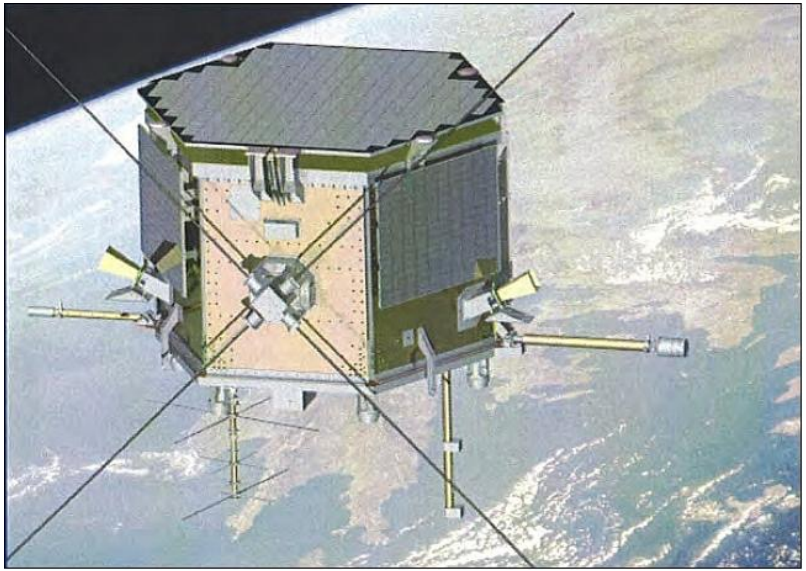
e-POP on CASSIOPE (aka Swarm-E)



e-POP on CASSIOPE

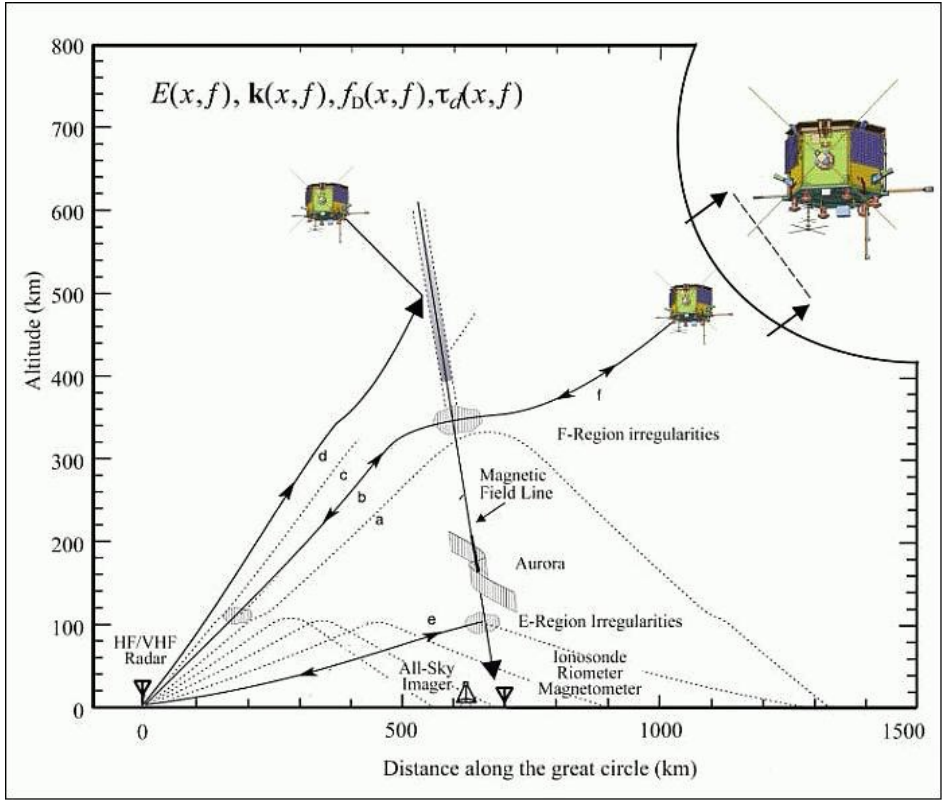
- **CASSIOPE** (CAScade, Smallsat and IOnospheric Polar Explorer)
  - Launched September 29, 2013.
  - 1310 x 349 km polar orbit.
  - Swarm-E, science operations supported by the European Space Agency (ESA)
- **e-POP** (enhanced Polar Outflow Probe)
  - 8 instruments (5.5 working).
- Science objectives are to study energization processes of the Earth's ionosphere at very small scales.

The Radio Receiver Instrument (RRI)



- **RRI** (Radio Receiver Instrument)
  - 4, 3-m monopole antennas.
  - Study radio emissions at 10 Hz to 18 MHz.
  - 31 kHz pass band.
  - 62.5 kHz I/Q sampling.
  - Target: natural and artificial radio emissions.
  - Natural: whistlers, auroral hiss, etc…
  - Artificial: radars (over the horizon), HAARP, etc…
- Study HF radio propagation in the ionosphere.
- Study F-region density structures.

The Radio Receiver Instrument (RRI)



Radio Science article

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AGU100 ADVANCING EARTH AND SPACE SCIENCE

Radio Science

RESEARCH ARTICLE

10.1029/2017RS006496

Key Points:

- Amateur radio transmissions are used to detect plasma cutoff and single-mode fading
- Fundamental ionospheric characteristics and magnetoionic phenomena can be studied with amateur radio transmissions
- New and compelling radio science experiments are possible with the participation of citizen radio scientists

Supporting Information:

- Figure S1
- Audio S1
- Audio S2

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Citizen Radio Science: An Analysis of Amateur Radio Transmissions With e-POP RRI

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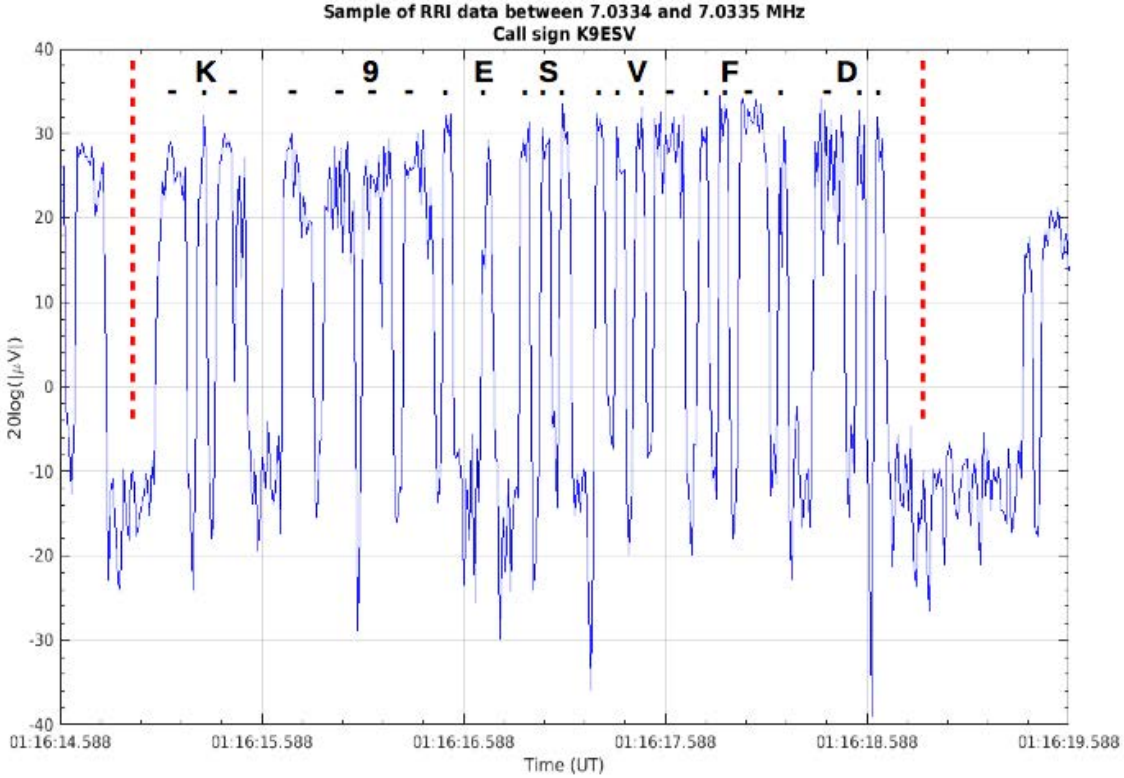
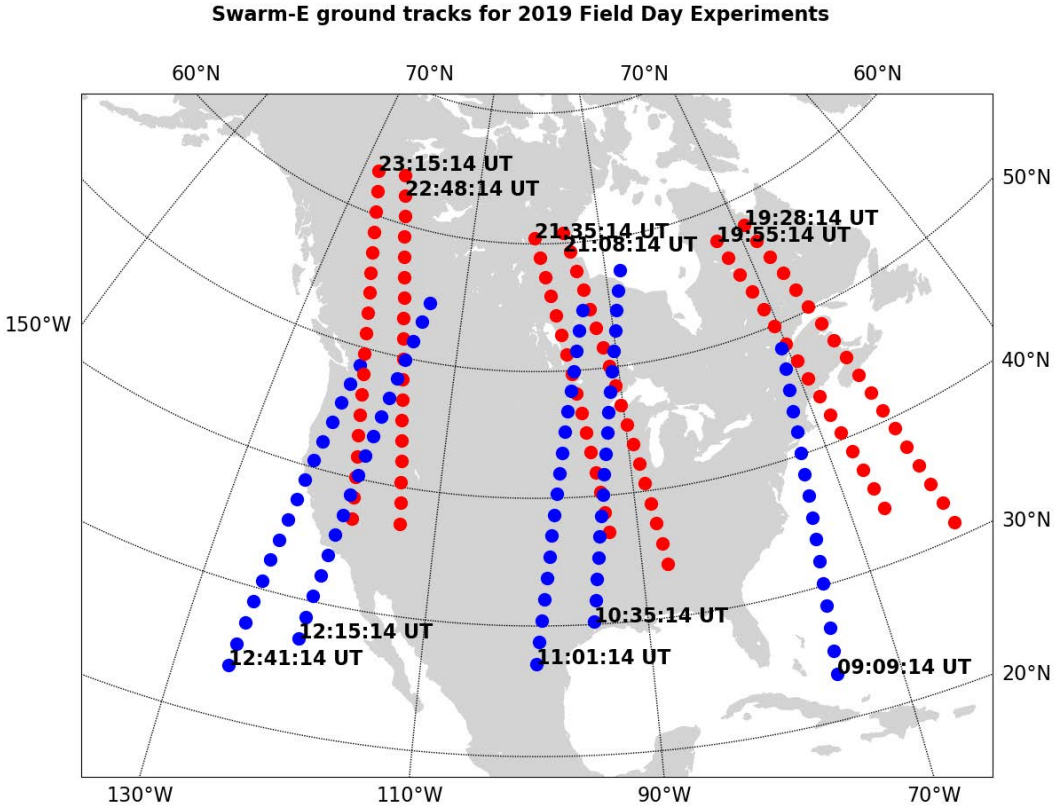
Abstract We report the results of a radio science experiment involving citizen scientists conducted on 28 June 2015, in which the Radio Receiver Instrument (RRI) on the Enhanced Polar Outflow Probe (e-POP) tuned in to the 40- and 80-m ham radio bands during the 2015 American Radio Relay League Field Day. We have aurally decoded the Morse coded call signs of 14 hams (amateur operators) from RRI's data to help ascertain their locations during the experiment. Through careful analysis of the hams' transmissions, and with the aid of ray tracing tools, we have identified two notable magnetoionic effects in the received signals: plasma cutoff and single-mode fading. The signature of the former effect appeared approximately 30 s into the experiment, with the sudden cessation of signals received by RRI despite measurements from a network of ground-based receivers showing that the hams' transmissions were unabated throughout the

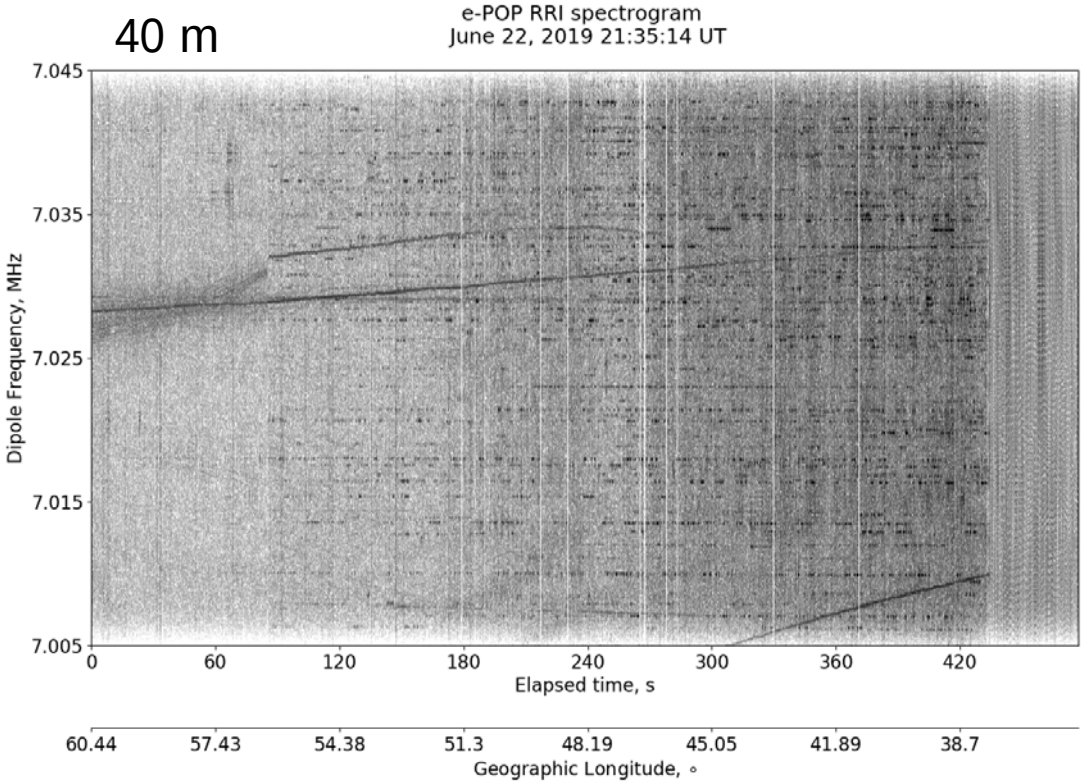
2015 ARRL Field Day: K9ESV



2019 Field Day results (a first look)



2019 Field Day results (a first look)



“Golden Ears Project”

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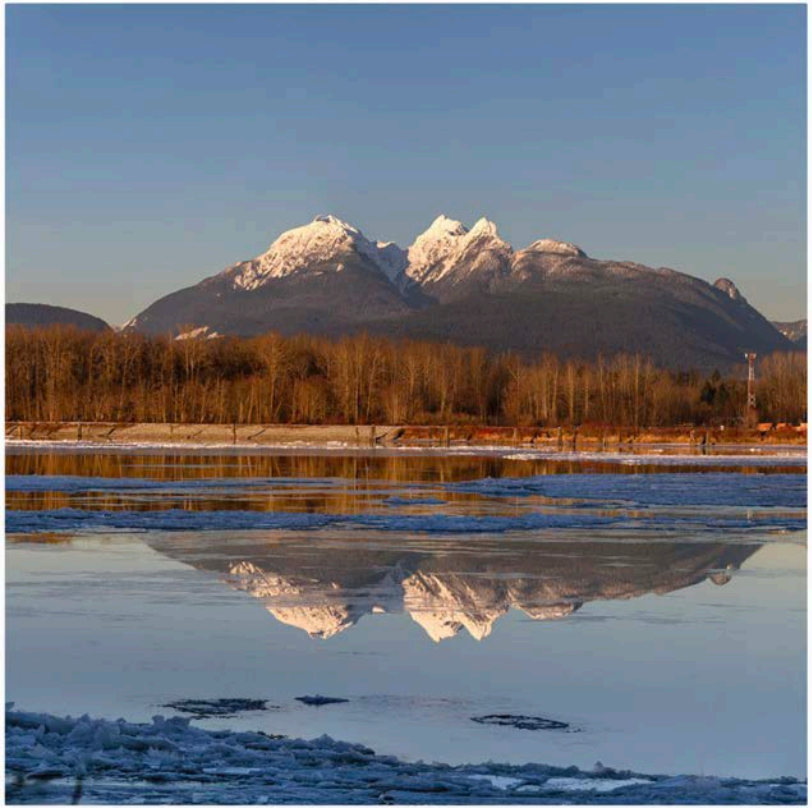
- “Skimmers” have difficulty decoding CW received by RRI.
  - The transmissions exhibit too much “flutter”, e.g., scintillation.
- In 2015, the call were signs are decoded aurally.
  - Easy if you only expect to detect 10-20 hams, but not 100-200.
- To scale up, we can either write a new skimmer or we can “work smart, not hard”.
- Rely on the generosity of CW operators with “Golden Ears” to decode the hams for us.

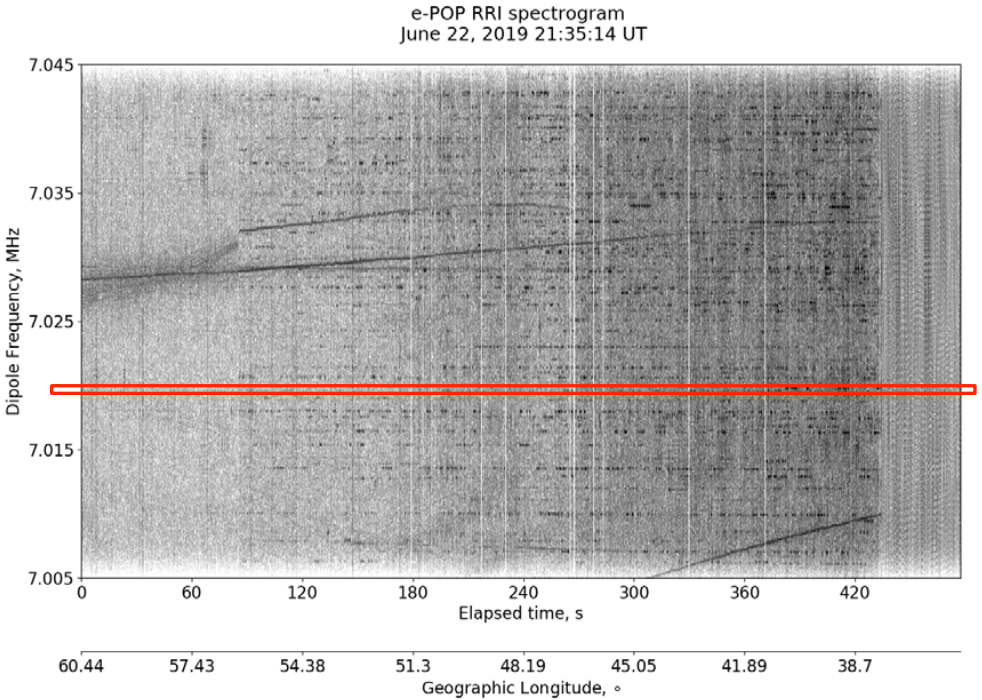
“Golden Ears Project”



Golden Ears mountains with the Fraser River in the foreground, viewed from Langley, British Columbia, Canada.

Photo by Michael Russell: https://fineartamerica.com/profiles/2-michael-russell/shop

Golden Ears Project (procedure)



- We “channelize” our RRI’s passband into 500 Hz channels, record the data to a .wav file.
- Two channels in the .wav file, a channel for each of RRI’s dipoles.
- Do this for entire passband - >100 .wav files ~10 minutes in length each.
- Provide Golden Ears citizen scientist with a like to the audio files and a spreadsheet.
    - Lots of listening!

Golden Ears Project (first results)

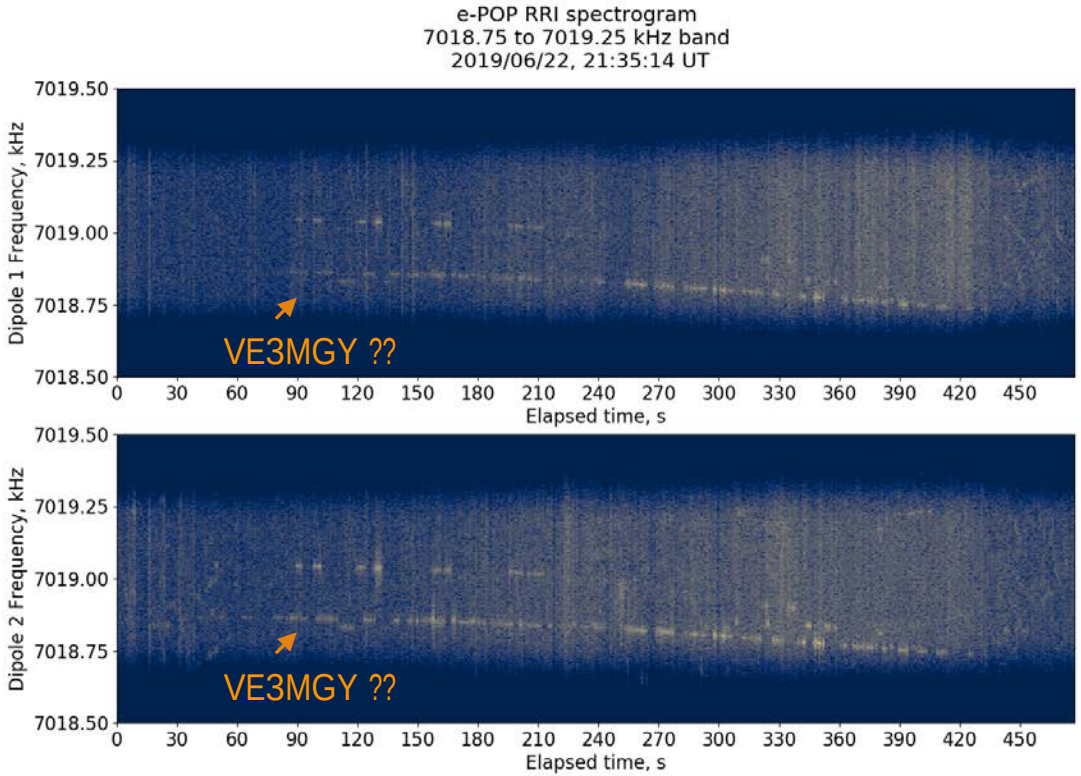
W1XP - Bob Reif

	A	B	C	D	E	F	G	H	I	J	K
1	Filename	Seconds In	Duration	Call Sign	Channel	R	S	T	RST Suffix	Channel Asymmetry	Fading
2	RRI_20190622_213514_214310_7002100_7002600.wav										
3	7003050.wav										
4	7003950.wav	382	4	WD9CIR	Both						
5	7004850.wav	138	192	W3EM	Both	3	3	9			In and out
6		364	48	K8LGN	Both	5	5	9			
7		412	22	W9GO	Both	5	7	9			
8	7005300.wav	107	43	N8G	Both						
9		135	89	K5EOK	Right	5	5	9			
10		135	277	K8LGN	Both						
11		292	28	K8ESQ	Both	5	5	9			
12		292	22	W9GO	Both	See notes					
13	7005750.wav	132	3	See Notes	Both	5	7	9			
14	7007100.wav	50	408	N9SIA	Both	See notes					
15											
16											

K1BG - Bruce Blain

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	Filename	Seconds In	Duration	Call Sign	Channel	R	S	T	T Su	hannel Asymmetr	Fading	Notes	
2					Left (1), Right (2), Both.					Left (1), Right (2), N	Yes, No		
3	0_7018750-7019250.wav	3.4		VE4B		559							
4	0_7018750-7019250.wav	33											
5	0_7018750-7019250.wav	1:29	2:16	K0DIT		559						Through this whole recording, VE3MGY cal	
6	0_7018750-7019250.wav	2:30	3:30	VE3MGY		549							
7	0_7018750-7019250.wav	2:40		NG7A		549						Answers VE3MGY	
8	0_7018750-7019250.wav	3:21	4:03	VE3MGY		439							
9	0_7018750-7019250.wav	4:14	4:39	VE3MGY		559							
10	0_7018750-7019250.wav	4:49		VE3MGY		559				Back and forth			
11	0_7018750-7019250.wav	4:59	7:07	VE3MGY		569							
12	0_7018750-7019250.wav	5:47		K5EOK		559						Answers VE3MGY	
13	0_7018750-7019250.wav	6:27		W3TS		549						Answers VE3MGY	
14													

Golden Ears Project (first results)



- A sampling of the channelized data.
  - 7018.75 - 7019.25 kHz
- Very nice and encouraging first results.
- Continuous monitoring allows us to see the Doppler shift.

Future Work and Summary

- **The ultimate goal is to use this data to use it to advance solar-terrestrial science.**
- We can leverage RRI's high sampling frequency (62.5 kHz) to study radio scintillation in the HF bands at very high resolution.
    - Scintillations may be due to multi-path propagation effects, e.g., (Perry et al., 2017), and/or presence of plasma density irregularities.
- Other electrical engineering/signal analysis flavored projects possible as well.
    - It may be possible to develop a decoder based on the Golden Ears results, improving on the CW skimmers (one example).
    - Could we use CW call signs detected by the Golden Ears to build an autocorrelation function?

Future Work and Summary cont…

- Maintain the steady progress of decoding (thanks to the Golden Ears).
  - Perhaps scale up? Include more members?

- **We can do radio science using ham transmissions as an HF source.**
  - **Not simply “for fun” but genuine space physics can be done.**
- **<u>Hams are a great ally for solar-terrestrial physics.</u>**