North Texas NTMS Microwave Society

Starlink Satellite Leakage

NTMS meeting
May 10, 2025
KM5PO

What is it?

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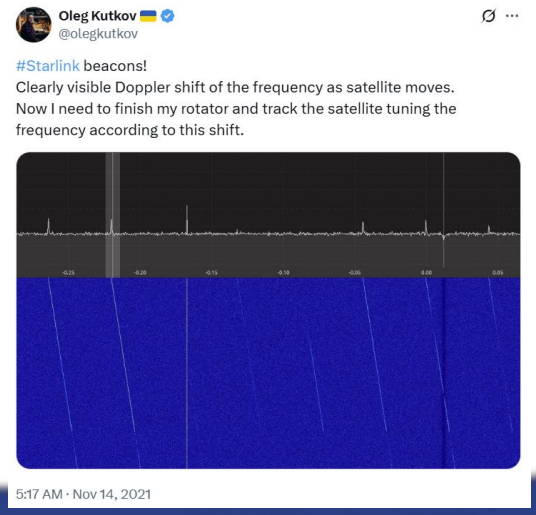
- Amateur radio operators and Satellite signal receiving enthusiasts have been searching for narrowband signals from Starlink and other Constellation based Satellite systems for at least 20 years.

Receiving Starlink satellite beacons on a budget

25 November 2021

SGCDEREK blog page - Info on setting up to receive Starlink leakage

Olev Kutkov personal blog



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Academic research

Signal Structure of the Starlink Ku-Band Downlink

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University of Texas at Austin Starlink signal structure study

***Abstract*—We develop a technique for blind signal identification of the Starlink downlink signal in the 10.7 to 12.7 GHz band and present a detailed picture of the signal's structure. Importantly, the signal characterization offered herein includes the exact values of synchronization sequences embedded in the signal that can be exploited to produce pseudorange measurements. Such an understanding of the signal is essential to emerging efforts that seek to dual-purpose Starlink signals for positioning, navigation, and timing, despite their being designed solely for broadband Internet provision.**

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Academic research

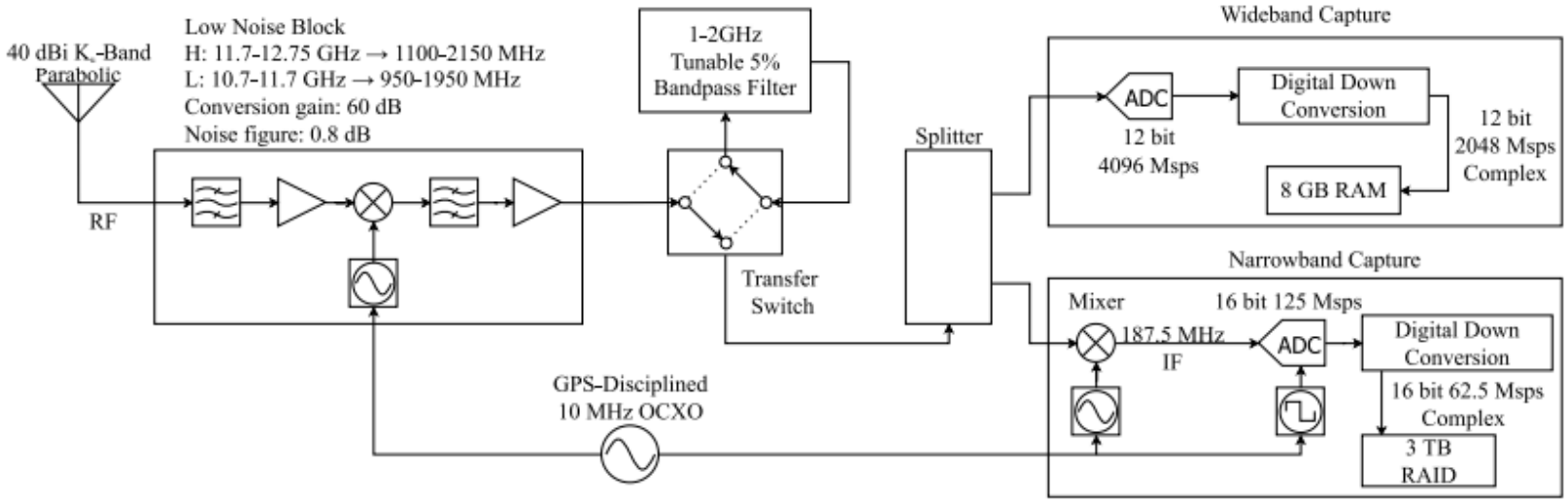

Fig. 1: Block diagram of the Starlink signal capture process.

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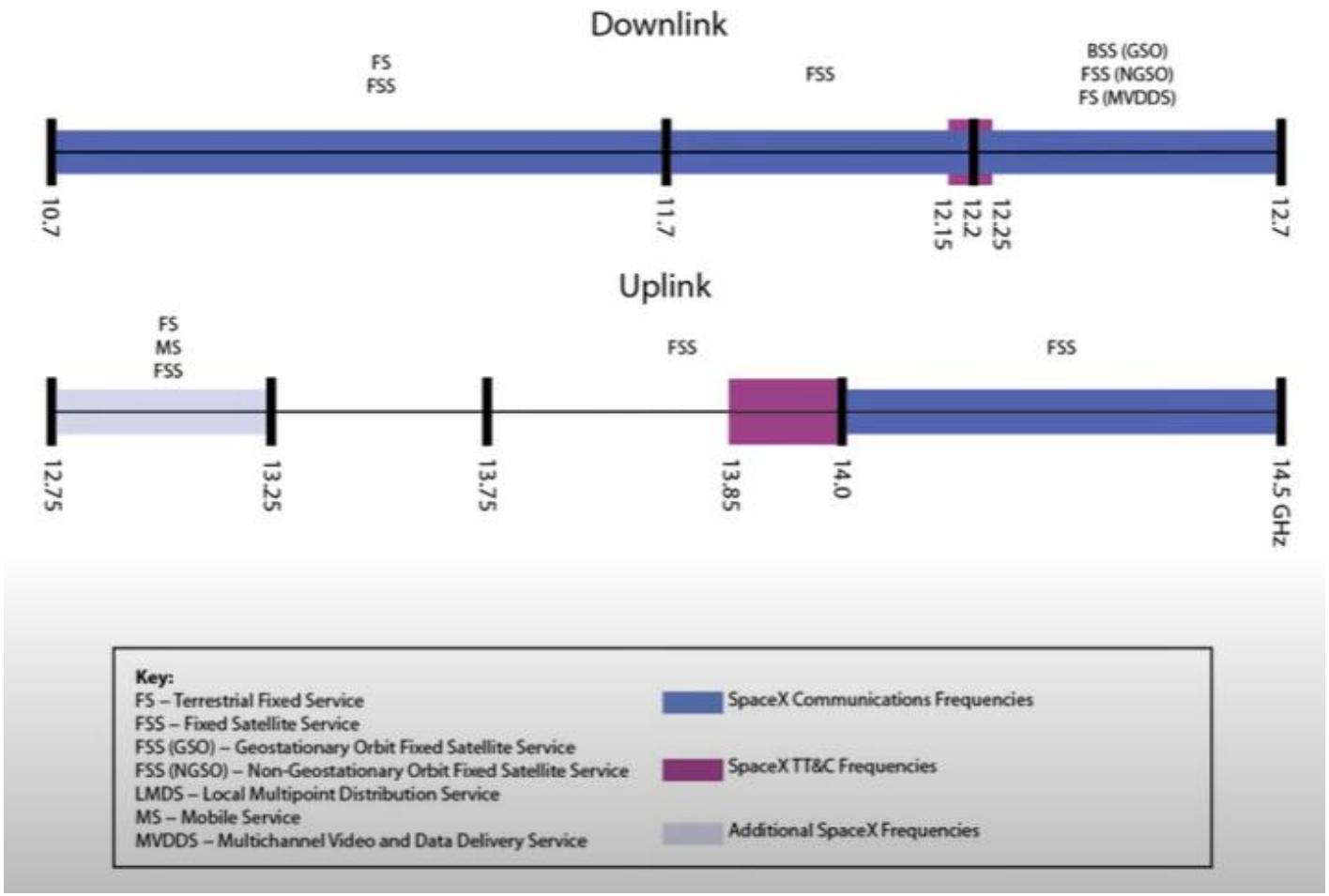
Spectrum usage



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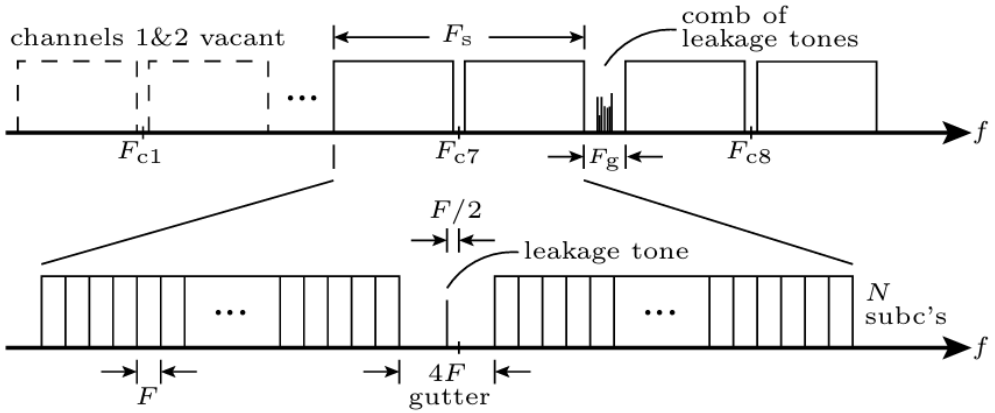
Starlink Channel structure

TABLE II: Starlink Downlink Signal Parameter Values

Parameter	Value	Units
F_s	240	MHz
N	1024	
N_g	32	
T_f	1/750	s
T_{fg}	$68/15 = 4.5\overline{33}$	μs
N_{sf}	302	
N_{sfd}	298	
T	$64/15 = 4.2\overline{66}$	μs
T_g	$2/15 = 0.1\overline{33}$	μs
T_{sym}	4.4	μs
F	234375	Hz
F_{ci}	$10.7 + F/2 + 0.25(i - 1/2)$	GHz
F_δ	250	MHz
F_g	10	MHz



- Channel layout for the Ku-band Starlink downlink.

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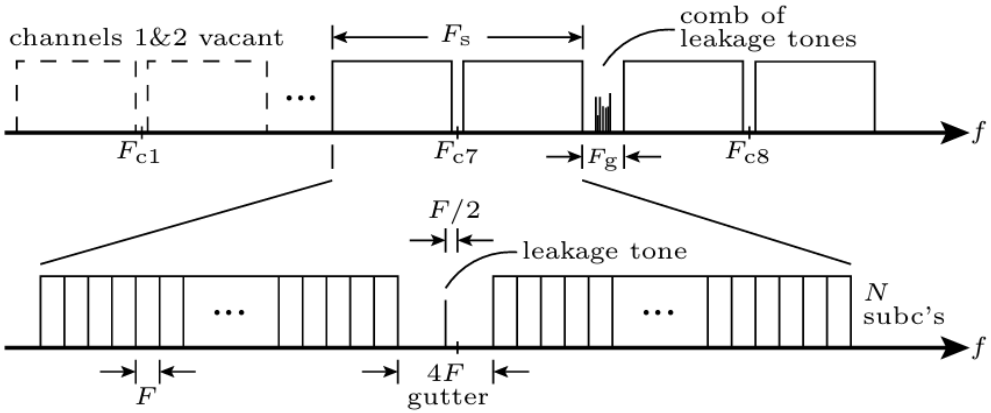
Leakage tones



Each channel's central four subcarriers are vacant, leaving a mid-channel gutter. Reserving such a gutter is a common practice in OFDM; otherwise, leakage from a receiver's mixing frequency may corrupt central information symbols. In Starlink's case, a transmitter-side leakage tone is present in some gutters for some satellites. For example, a leakage tone was found in the gutter of channel 5 on the Starlink satellite with identifier 3262, channel 6 on Starlink 3503, and channel 5 on Starlink 2409, whereas for other satellites no leakage tones were observed for the same channels. Interestingly, the ith channel's center frequency, F_{ci}, is $F/2$ higher than the channel's midpoint, which lies in the center of the mid-channel gutter. A gutter leakage tone, if present, resides at the channel midpoint.

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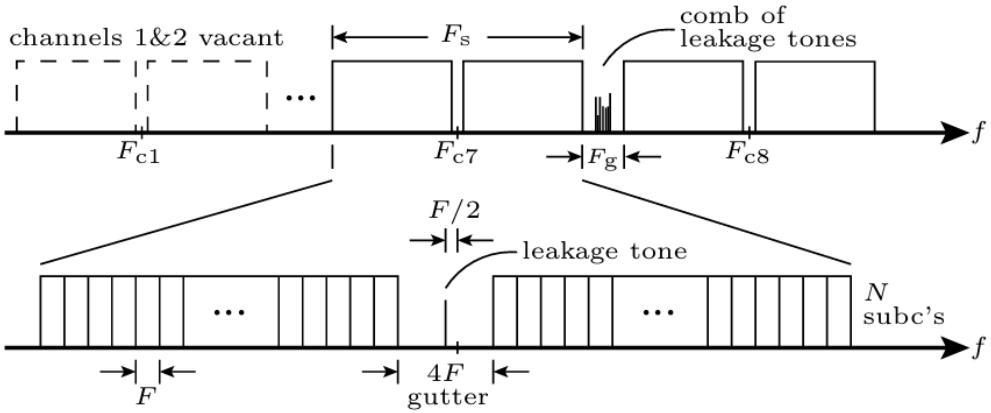
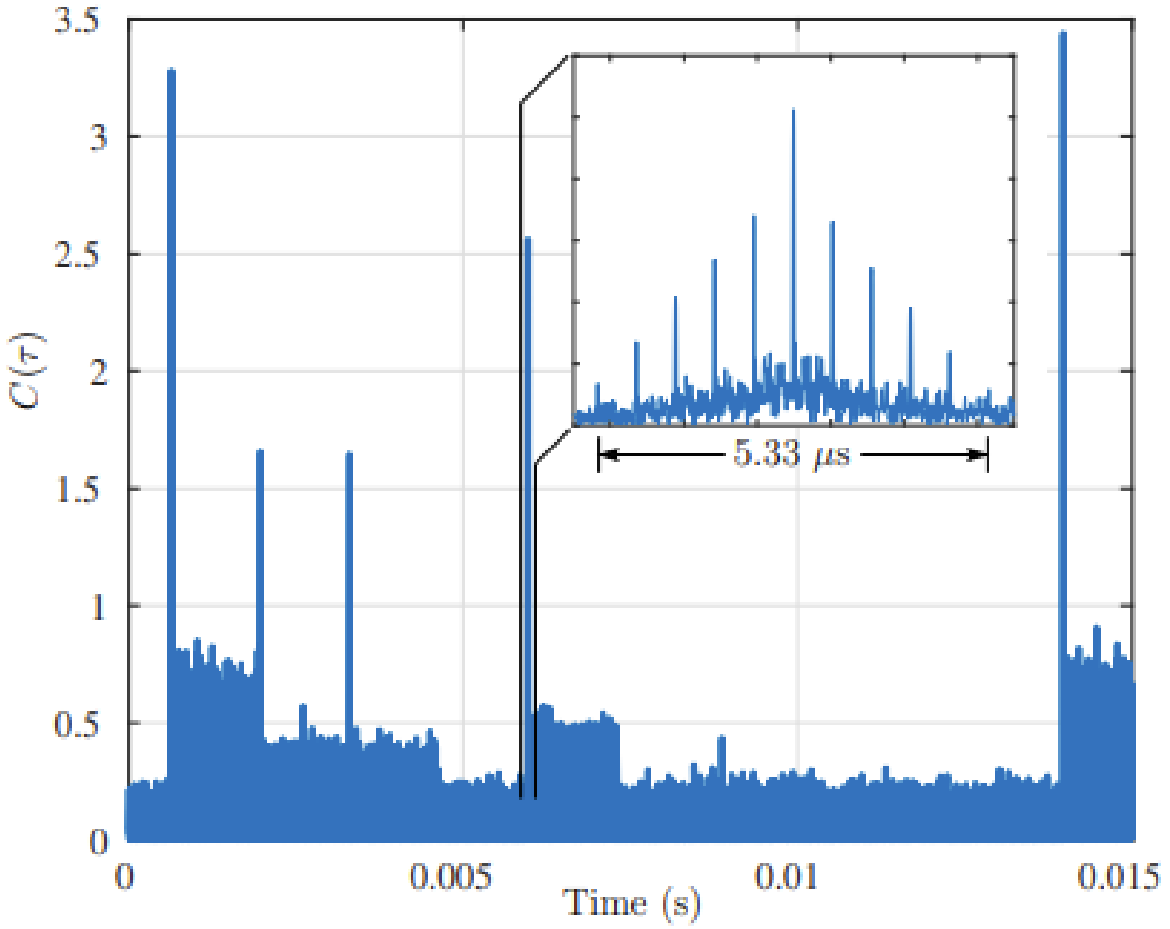
Leakage tones



A guard band with a generous bandwidth $F_g = 10$ MHz separates adjacent channels. Within some guard bands there appears a comb of 9 leakage tones uniformly spaced over a bandwidth of approximately 350 kHz. For example, such combs were observed between channels 5 and 6 on Starlink 2024, between channels 5 and 6 on Starlink 1184, and between channels 7 and 8 on Starlink 2423, whereas for other satellites no combs were observed between the same channels. Interestingly, the between-channel combs of tones, when present, persist between frames, whereas the mid-channel gutter leakage tones, when present, only appear during the interval of a broadcast frame.

We suspect that the between-channel tones may be the tones tracked in [6], [7] and [8] to perform Doppler-based positioning with Starlink. We note that neither the mid-channel gutter tones nor the between-channel tones appear deliberate: their presence and amplitudes are not consistent from satellite to satellite, and the between-channel tones appear to vary in amplitude with beam adjustments.

Between channel (comb) leakage tones



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Simple receiver

- Low cost LNB with 9750 MHz LO
- Bias T
- SDR (RTL-SDR dongle works great)
- SDR software (GNUradio, SDR Console, SDR Angel, etc)

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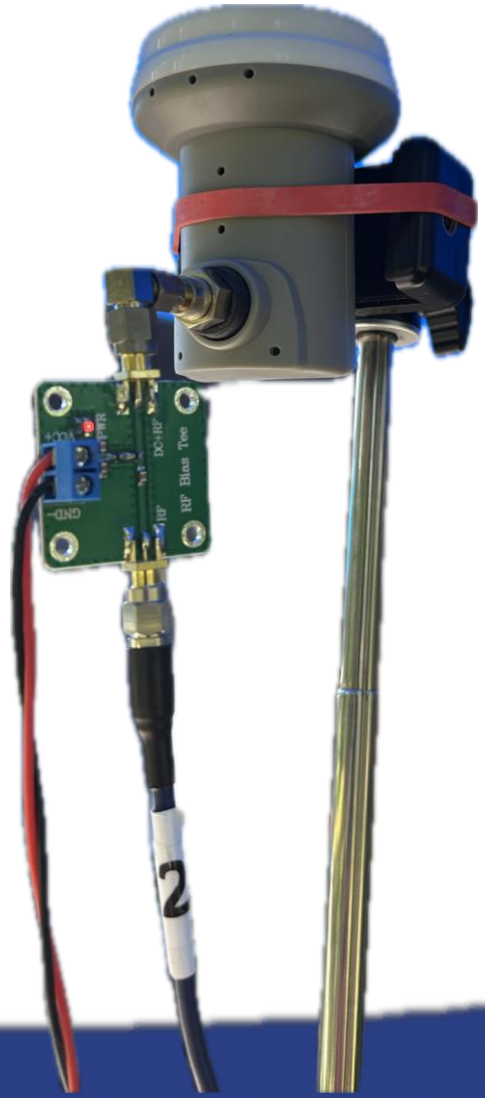
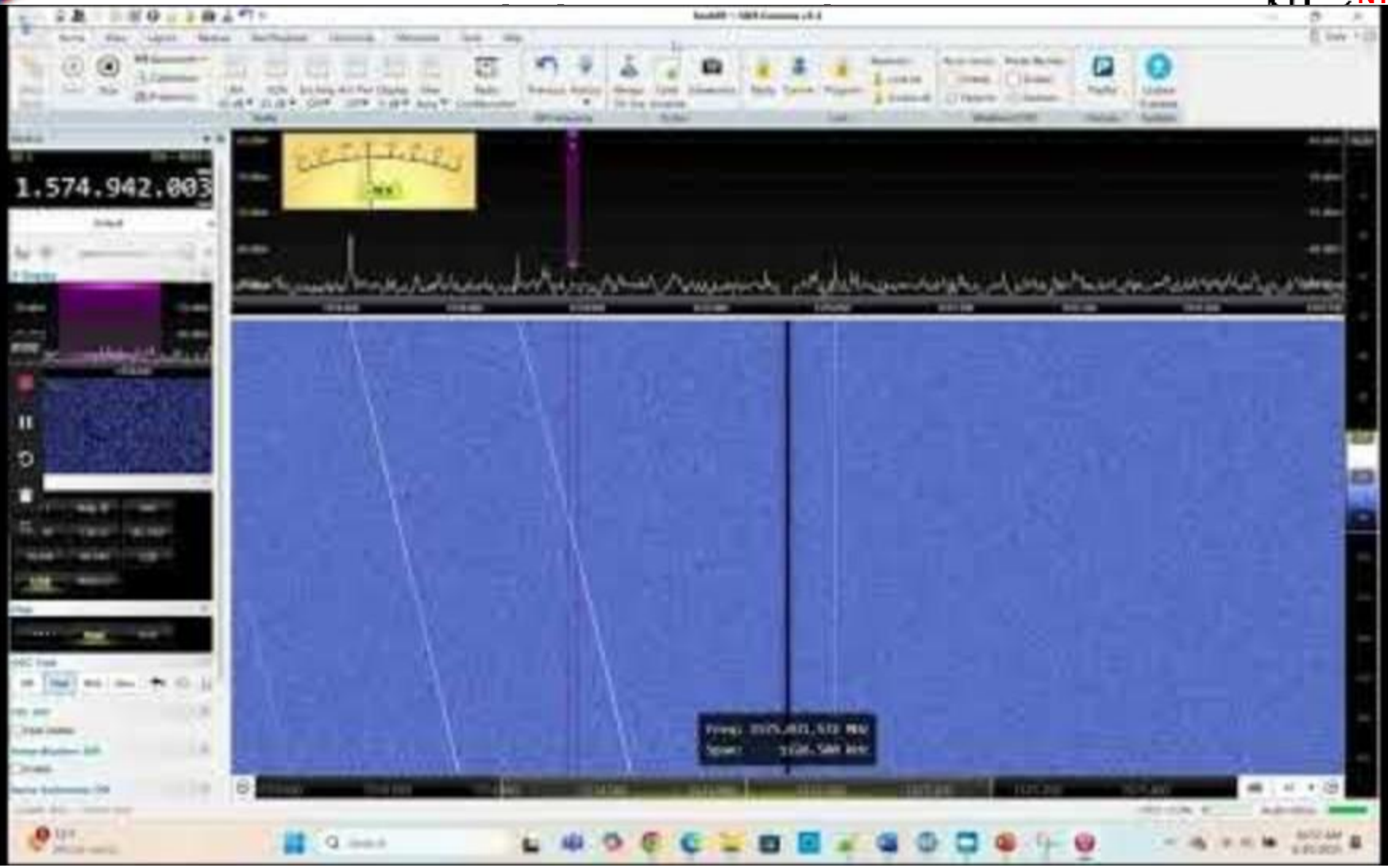
Simple receiver

- HackRF and mounted LNB

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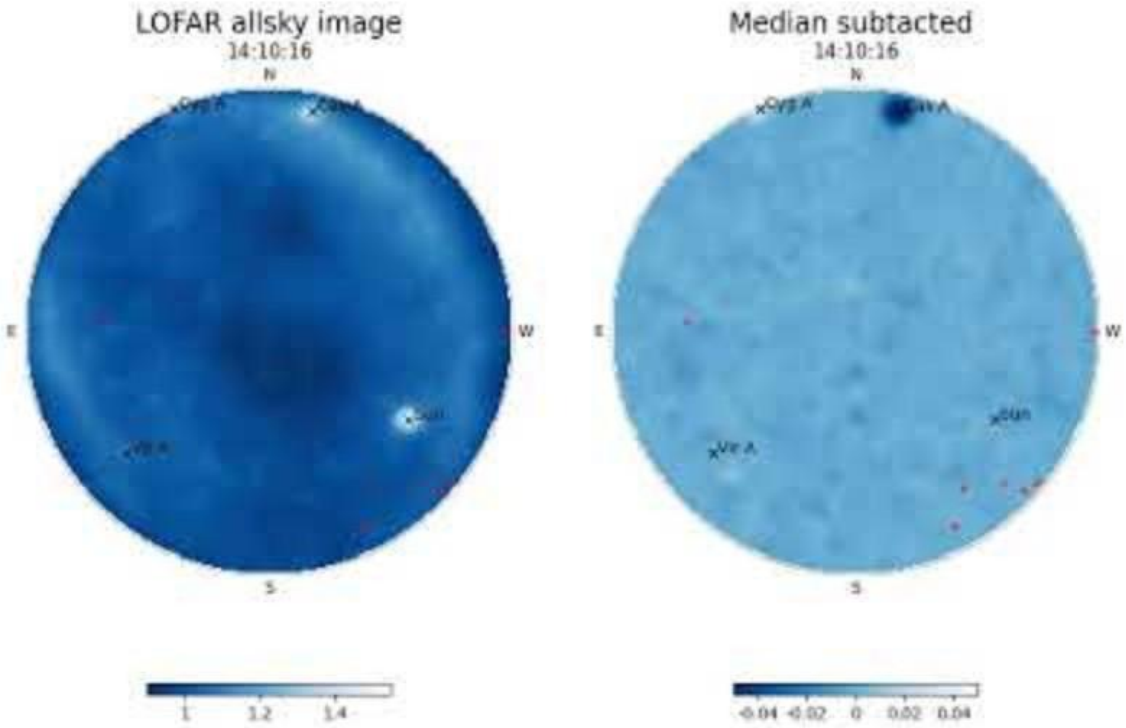
LOFAR study



References

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Questions?

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