NOAA GOES DCS Radio Frequency Interference and Mitigation

Presented by

Microcom Design, Inc.

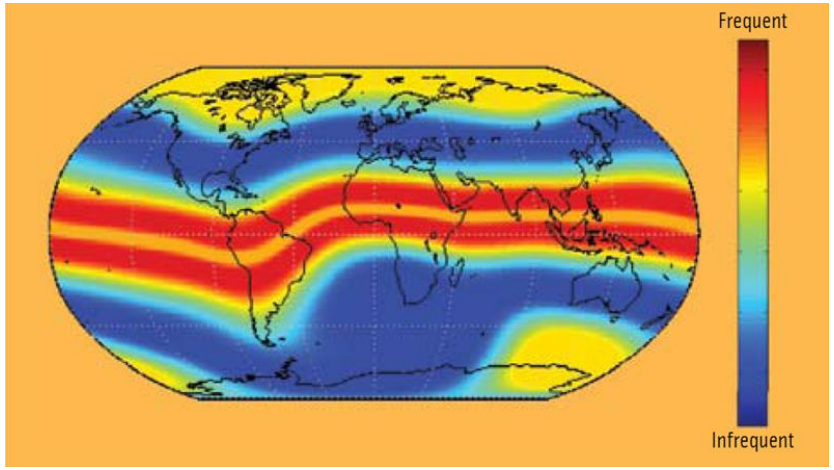
April 2023

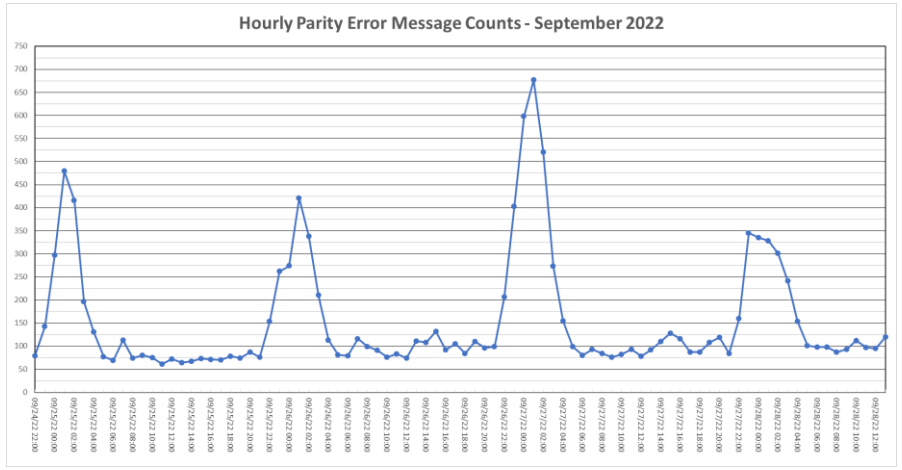
DCS Interference – Overview

- Interference on the GOES Data Collection System is nothing new, and has been dealt with since its inception.
  - All radio frequency links are subject to interference (RFI).
  - Satellite RF links are more susceptible to RFI for the same advantageous reason that satellite communications has over line-of-sight communication … A satellites wide coverage area.
  - The GOES Satellites cover the entire Western Hemisphere, which means the RFI source can be anywhere from Canada to South America and from the Pacific to the Atlantic oceans.
- Interference can be in several forms or have different characteristics:
  - Local RFI at receive sites versus Satellite RFI (Cellular LTE vs. Terrestrial LMR walkie-talkies).
  - Downlink RFI versus Uplink RFI (L-Band: in or near 1680 MHz vs. UHF Band: in or near 402 MHz).
  - Narrowband or Wideband interference (affecting only 1 or 2 or impacting many channels).
  - Atmospheric: Ionospheric Scintillation and Weather Fading (currently not a major factor for DCS).
  - Systemic: Faulty or misconfigured DCPs.
- RFI can corrupt just a portion of the transmission (i.e. parity errors) or wipe out an entire message (i.e. a missing message).
  - DADDS captures such statistics, and the DCS team regularly monitors and reviews them.

DCS Interference – Ionospheric Scintillation

- Atmospheric phenomenon that locally disrupts an RF signal as it passes through the Ionosphere
  - Effect peaks up around Solar Maximum, which occurs roughly every 11 years (last max was in 2013)
  - Most significant around the equinoxes when sun is near the equator
  - Typically begins after sunset and last several hours (0-6 UTC).
  - Will affect tropical latitudes the most; within ±20º of the *magnetic* equator (dips into South America).
- Impact on DCS first identified in 2011/2012
  - Affects frequencies from 3 MHz to 2000 MHz – DCS Uplink @ 402 MHz; Downlink @ 1,680 MHz
  - Has always been occurring, but 300/1200 bps (HDR) signals are more susceptible than older 100 bps signals; plus HDR transition also resulted in more frequent transmission (hourly versus 3-4 hours).
  - Improved reception equipment (DAMS-NT) and database software (DADDS) helped in identification





DCS Interference – Ionospheric Scintillation Mitigation

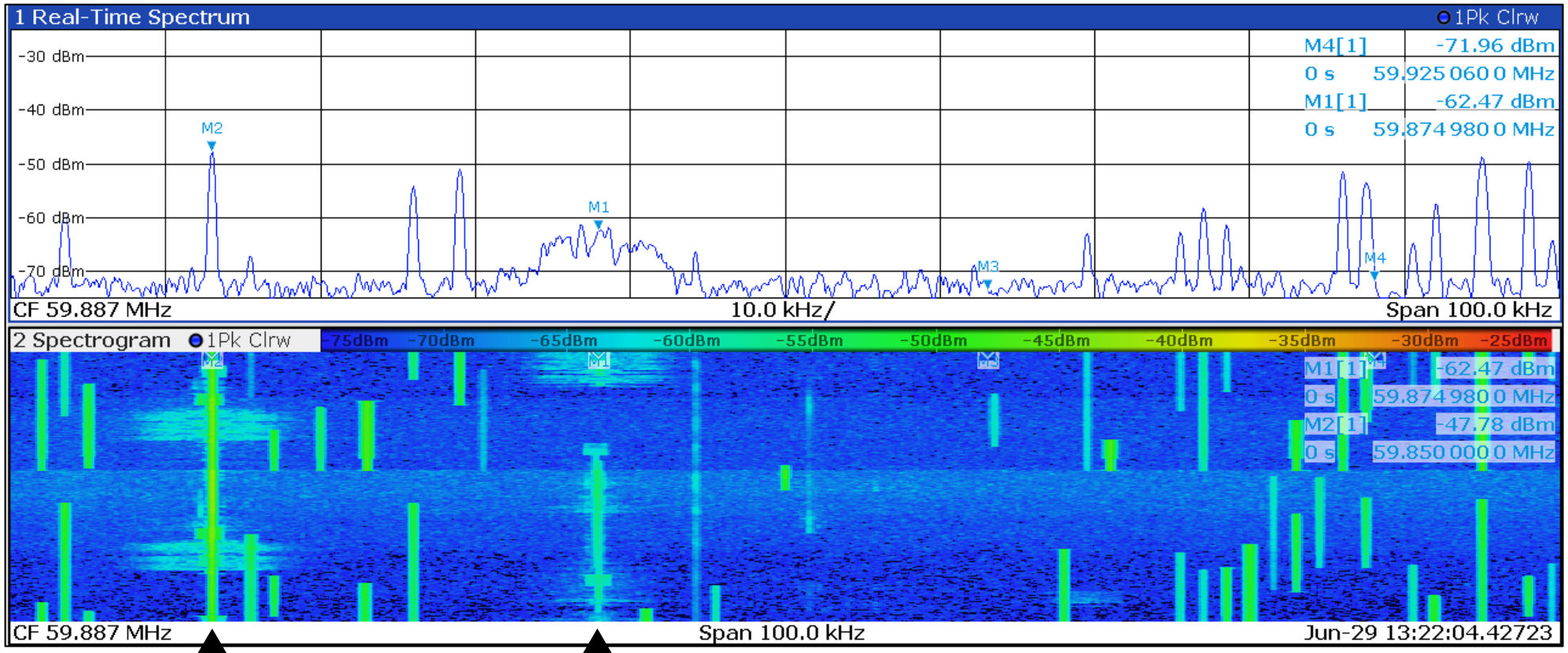
- Short-Term - Focus on Data Loss Mitigation
  - There is no immediate or easy solution to minimizing transmission impact from ionospheric scintillation other than sending data repeatedly.
  - Send prior data in each transmission:
    - Repeat data in 2 or even 3 transmissions where possible.
    - Use Pseudo-Binary (and Binary in the future) to reduce message length to allow for more/prior data.
- Long Term Options – Require Policy and/or System Changes
  - Reception from Multiple Paths?
    - Receive East channels from GOES-West, and vice versa – Only way to truly mitigate uplink Scintillation impact.
    - Combine/share data sets from multiple receive sites – Only way to truly mitigate downlink Scintillation impact.
  - More Frequent/Redundant Transmissions?
  - Use of Linear Polarized Antenna?
    - Since scintillation can affect the horizontal and vertical components of a circularly polarized transmission differently, using linear polarized antenna may improve transmission throughput.
    - Using linear polarization will require 3 dB increase in uplink power.
  - Use of a Two Way link to direct DCP's to resend data.
- Wait it Out and Accept Impact Every Decade or So?
  - Ionospheric Scintillation will never completely go away, but it's affects will gradually subside.
  - However, it will return around the maximum on the next solar cycle (2033-2035).

DCS Interference – Wideband Interference

- Previous example: Identified RFI coming from a Canadian agency studying green house gases.
  - The GHGSAT RFI was intermittently impacting numerous channels around channel 200.
  - With the help of an RFI geolocation company called Hawk Eye 360, the source of the interference was pinpointed, and NOAA was able to coordinate with the Canadian agency to mitigate the problem.
- Current example: FM Audio transmissions coming from Land Mobile Radios
  - Also known as General Mobile Radio Service (GMRS)
  - Signal first captured at WCDA on June 29, 2022
  - Has been impacting numerous East channels, and from time-to-time one or both Pilots on GOES-East.
    - When RFI impacts a Pilot, the interference can be translated to all transmissions being received.
  - Audio recordings of the transmissions were captured and distributed with the hope of determining the source of the interference.
    - It is believed the following languages have been eliminated: English, Spanish, Portuguese, French, and Arabic.
    - A NOAA employee at WCDA cleaned up the audio recording and believes it sounds like Jamaican Patois ; (Per visitjamaica.com … "broken English, heavily influenced by our African, Spanish, French, and English colonial heritage")
    - The audio clips were short and somewhat garbled since there were naturally active DCP transmitters using these frequencies as well.
- Attempts to geolocate the source of this RFI have so far been unsuccessful, but the effort is ongoing, and NOAA hopes to have Hawk Eye 360 perform additional scans in the near future.

Wideband Interference – LMR Capture on June 29, 2022

Real Time Spectrum Analyzer capture from WCDA

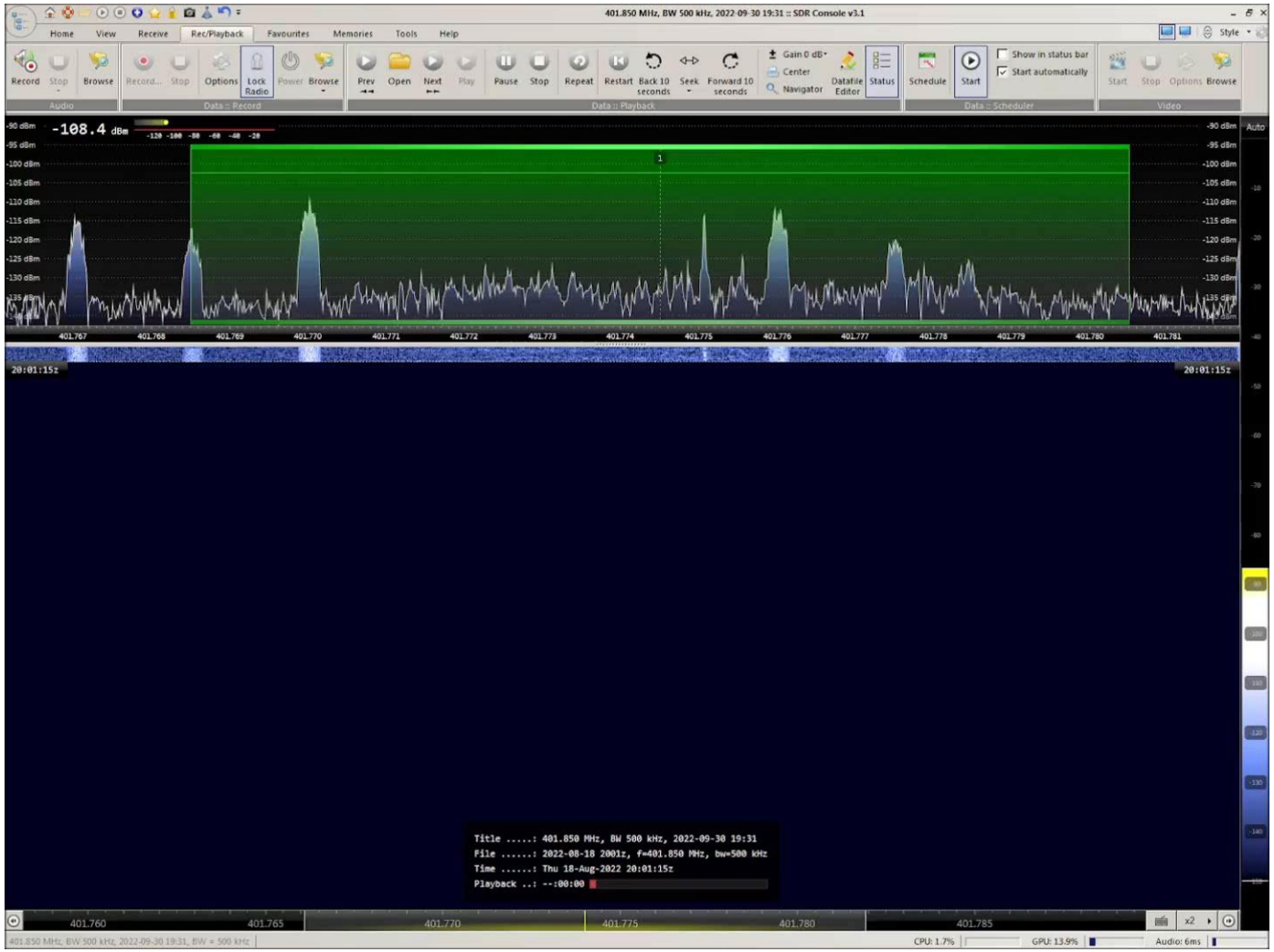


Primary Pilot

Ch. 117

LMR RFI - SDR RTSA Interference Example Channel 50

Upper Section: Shows live signal amplitude versus frequency.



Lower Section: Provides waterfall plot of signal intensity over time. Brighter color indicates a stronger signal.

LMR RFI – Ongoing Mitigation Steps Taken by NOAA

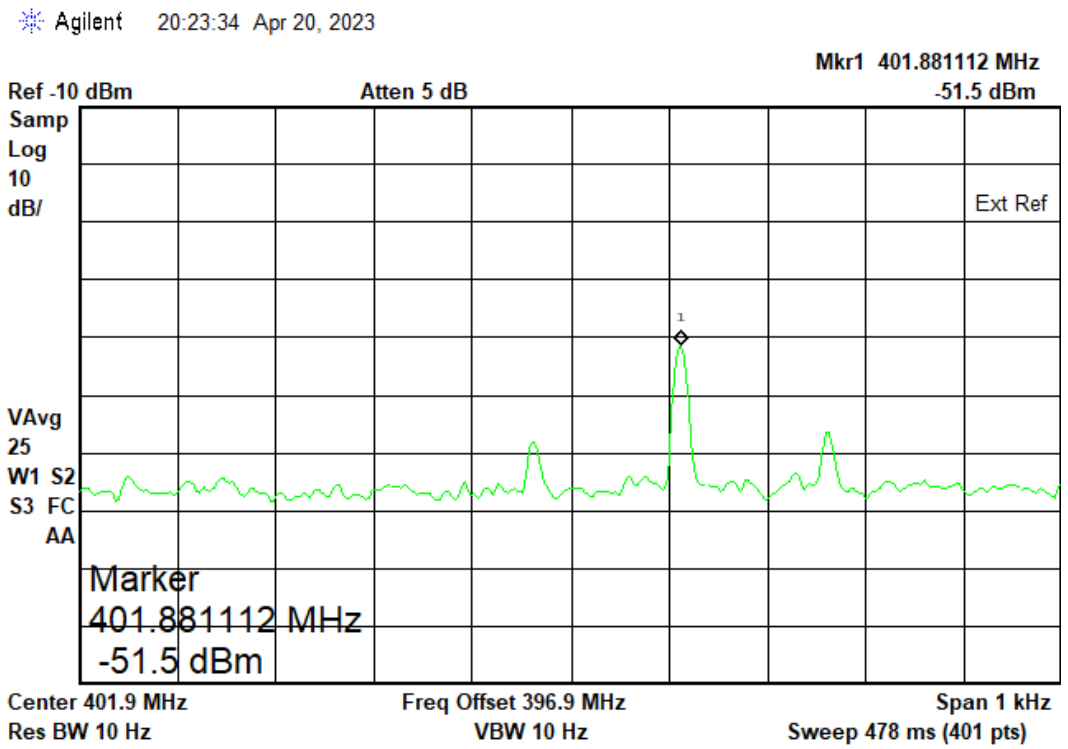
- WCDA Personnel Actively Monitor for RFI on the Pilots
  - When LMR RFI is impacting the active Pilot, Wallops operators will switch both the WCDA and NSOF receive systems to the alternate Pilot.
  - In September 2022, the new Backup Pilot uplink system at CBU was brought online, and the two Pilots are extremely well matched and the Backup is significantly more stable.
- Reception of Key East Channels on GOES-West DAMS-NT
  - Since interference was not impacting GOES West, spare DEMODS in the GOES West system were tuned to the most impacted GOES East channels.
  - Prior testing by Microcom and mitigation due to satellite outages has shown that ~70% of DCS messages can be received via the alternate spacecraft.
  - An analysis by Microcom in early October indicated that several hundred messages per day are being received good on GOES-West that are corrupted on GOES-East
    - On October 1ST over 1,500 DCS messages were saved by this mitigation step.
- Partners in the Coordination Group for Meteorological Satellites (CGMS) have been made aware of the situation, and a joint summary of all DCS RFI is in the works.

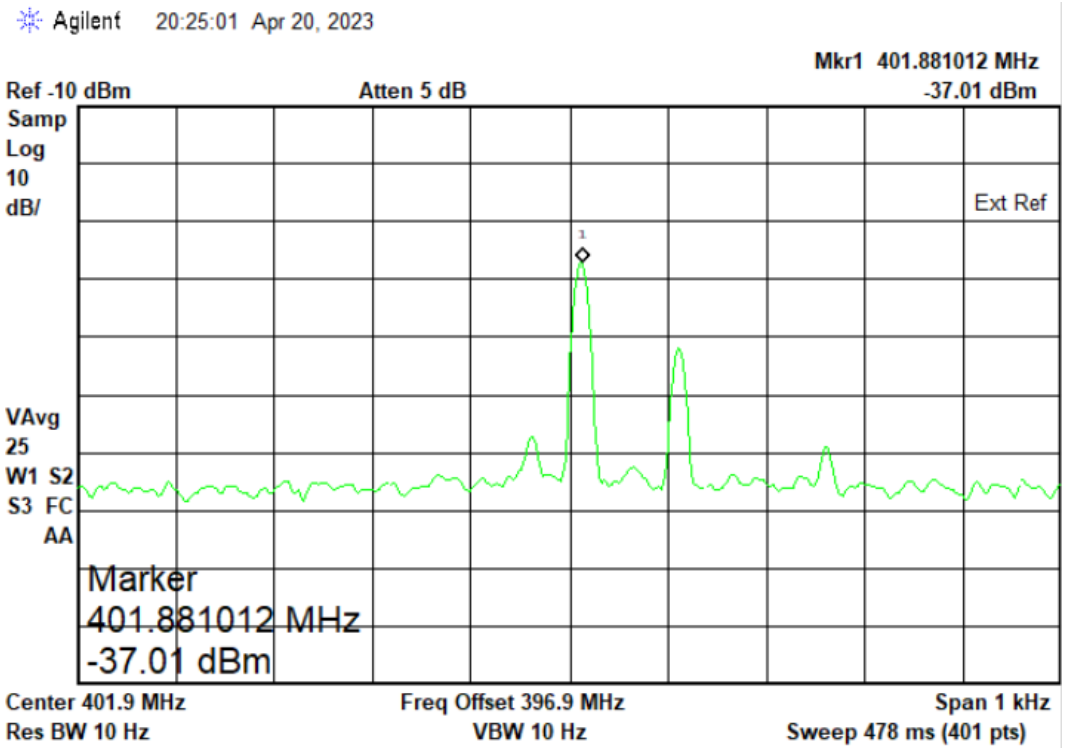
DCS Interference – Narrowband Interference and Mitigation

- Narrowband interferers generally resemble a Pilot:
  - A continuous or constant carrier signal or tone.
  - There is no modulation or variation in the signal that is attempting to convey identification or information.
  - Microcom does believe that some of these interfering signals could be coming from faulty DCPs.
- Microcom and NOAA are currently tracking more than a half a dozen narrowband interferers.
  - Some interferers are currently having negligible impact since they are either low in signal level or not in an active GOES domestic channel.
  - Some interferers are an indirect impact by taking away the reserved tertiary Pilot frequency of 402.00 MHz.
    - If continuous RFI was impacting the either the Primary Pilot (401.85 MHz) or the Backup Pilot (401.70 MHz), NOAA is supposed to be able to switch the affected Pilot to this third frequency, but cannot due to the existing RFI.
  - One interferer is directly impacting channel 121.
- To partially mitigate the interference in channel 121, the demodulators on this channel have had been adjusted to raise their signal lock threshold.
  - This prevents the demodulators from getting "stuck" on this signal and miss other DCP transmissions.
  - However, the signal can still cause errors in messages, especially when it is in the center of the channel.
  - Over the last couple of years the signal has drifted back and forth throughout the channel, but has never completely left channel 121.

Narrowband Interference – Channel 121

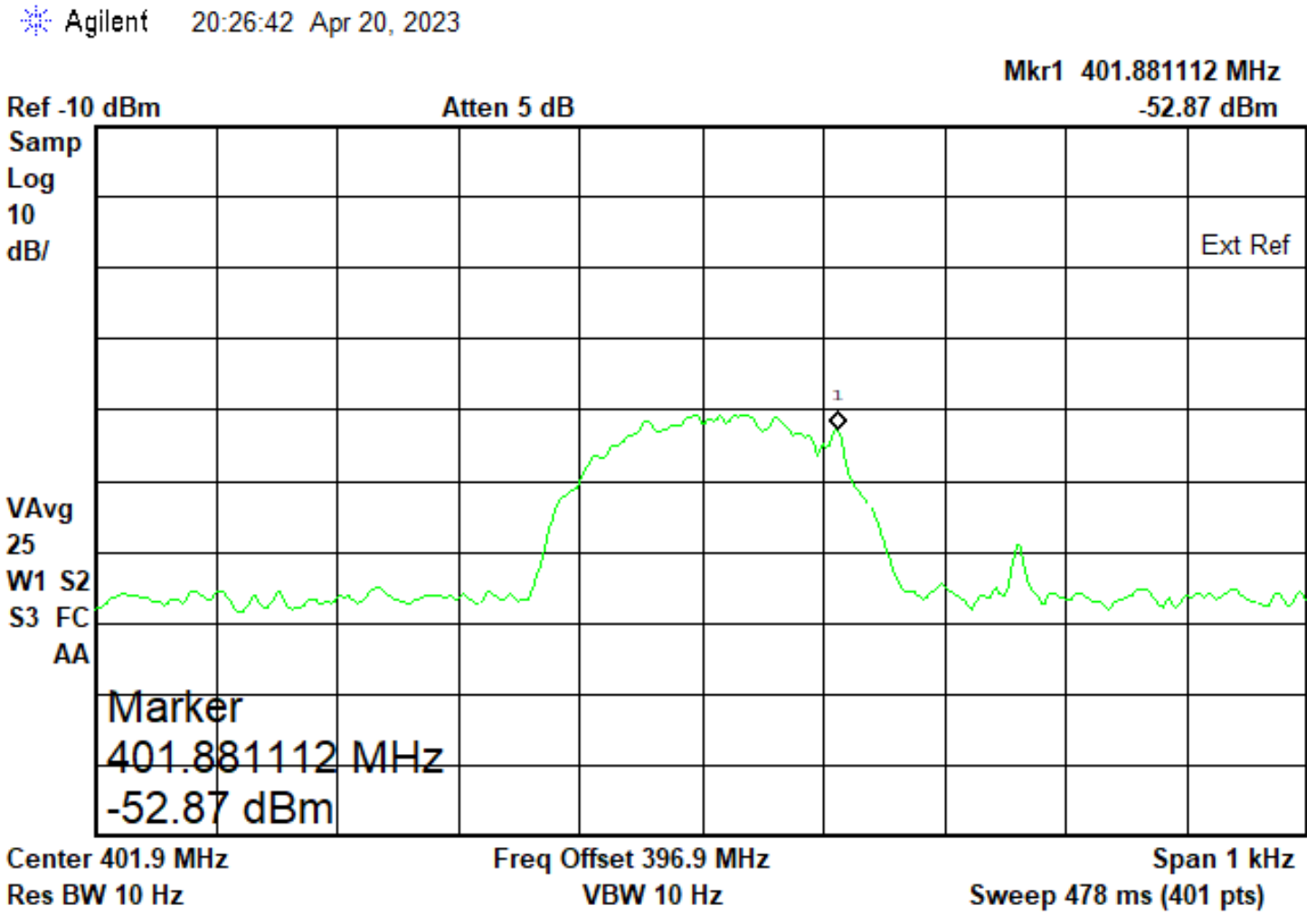
- Spectrum Analyzer capture on left shows just continuous interferer in 1 kHz BW of channel 121.
  - 150 Hz side tones suggest an errant DCP since the modulation rate for a 300 bps message is 150 symbols per second.
  - Peak level is 23.5 dBm below Pilot and only 14.5 dBm below carrier level of a CS2 transmission.
- Spectrum Analyzer capture on right shows the interferer along with a CS2 message carrier.
  - Signal is slightly off the channel (12 Hz), but strong enough and distinct enough for demod to lock.





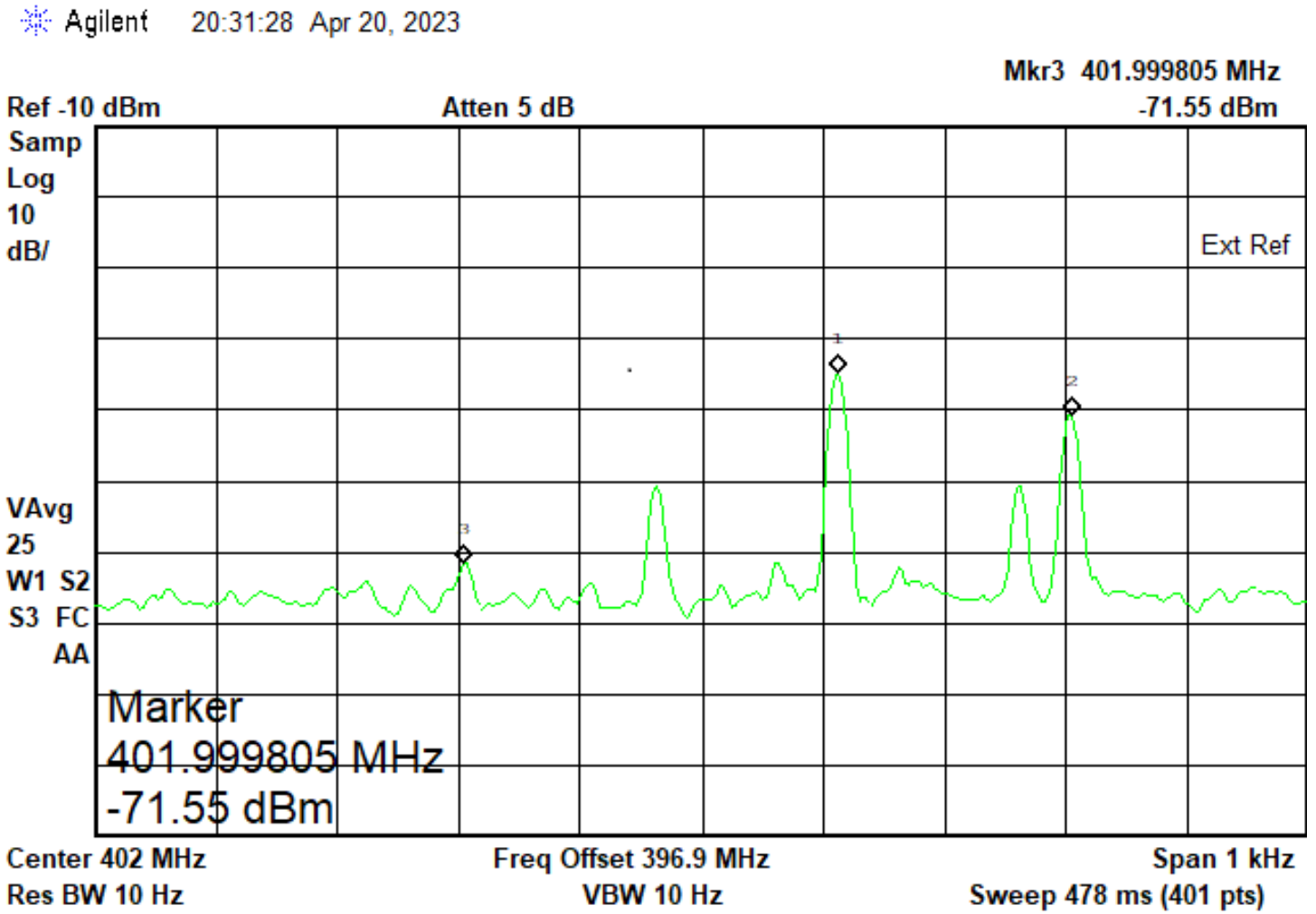
Narrowband Interference – Channel 121 with CS2 Message

- However, once the modulation begins to convey the DCP message data, the signal spreads out and encompasses the interferer.
- Due to the relative signal strength of the two, the interferer will most likely cause parity errors in the message data.
- When the interferer drifts to either end of the channel bandwidth, its impact is significantly reduced.



Narrowband Interference – Tertiary Pilot Location (402 MHz)

- There are several interfering signals around 402 MHz.
- Marker 1 identifies a signal similar to what is in channel 121.
  - Has 150 Hz side tones.
  - It may even be a related signal since it seems to move or drift identically.
  - Could be a "ghost" from the signal in 121.
- Markers 2 and 3 identify other unique interferers.
- All of these eliminate the use of 402 MHz for a Pilot.



Thank you for your attention!

Questions?

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