UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL ENVIRONMENTAL SATELLITE, DATA AND INFORMATION SERVICE

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SUBJECT: Position on Radio Frequency Interference: How should NOAA plan for it and address its impacts?

Scope: This memo provides background information and specific recommendations on RFI-related options that NESDIS should consider for the next-generation ground and space architectures planning and implementation.

Important note: *This memo was developed based on the deliberations and discussions among the core-SAT (federal employees only), following fact-finding and discussions of results and scientific facts with the general SAT.*

Executive Summary:

After several rounds of discussions at the general SAT, where multiple SMEs were invited to give varying perspectives and informative descriptions of the RFI situation and its likely evolution in the future, the core-SAT met and looked at several scenarios. Based on these core-SAT discussions, here are the highlights of the main findings and recommendations that resulted:

- *Fact:* There is ongoing pressure toward establishing communication services that use microwave bands and channels close to or overlapping with those used for Earth observations. Even when these communication channels are not overlapping with the Earth-sensing channels, their out-of-band filter requirements are not deemed stringent enough to prevent RFI contamination to the Earth-sensing protected channels . This risk is expanding with 5G communications services deployment and is expected to continue with future generation deployments (6G, etc) as well as from future FCC spectrum sales for other services . The Earth observing bands are driven by the physics of the Earth's atmosphere and therefore are not exchangeable .

- *Fact:* This RFI contamination issue has gained national and international attention, with the ECMWF organizing an international event to discuss this issue. This is a global issue that is being discussed by international agencies as the occurrence and magnitude of the RFI is also topography dependent, hence it is not constant in time and space, and there are insufficient resources allocated for routine RFI detection. Multiple international NWP centers and space and defense agencies are actively tracking this issue.

- *Fact:* All RFI contamination within environmental sensing bands is harmful. Strong RFI is problematic because of the loss of otherwise-useful observations. Low RFI contamination levels that are borderline detectable are of particular concern because contaminated data might escape detection, compromising multiple applications. Assimilating data without fully characterized error will limit their value for numerical modeling, leading to erroneous forecasts and reduced forecast skill, which would impact the NOAA mission of protecting life and property.

- *Fact:* Current RFI contamination has been observed in passive microwave frequencies. Growth in RFI contamination is expected to affect more frequencies in the future, further limiting NOAA's ability to accurately measure the environmental microwave signal. This is especially worrisome for the 50-58 GHz oxygen sensing band as it serves as one of the primary sources of information to infer atmospheric temperature in NWP applications. Internal NOAA studies and remote sensing experts have repeatedly highlighted that alternative channels such as the 118 GHz band are not a substitute for the 50 GHz band.

- *Fact:* It is currently hard to accurately assess the extent of this RFI contamination both spatially and temporally. We currently do not have a mechanism to routinely 'monitor' these potential contaminations.

- *Fact:* The remote sensing and users' communities using microwave data are concerned about the impact of growing RFI into the environmental sensing bands. They have several initiatives to work toward protecting the microwave spectrum that is dedicated to Earth remote sensing (e.g., CGMS working groups, etc.)

- *Fact:* The assessment of the impacts of potential RFI contaminations is difficult. The significance of impacts varies depending on the user. Accurate impact assessments are important to provide solid arguments when discussions and negotiations occur with spectrum regulators.

- *Fact:* Around the 23 GHz band, the impact of RFI contamination is deleterious in our ability to measure moisture (integrated) in the atmosphere.

- **Based on these facts, we recommend the following:**
    - **#1** We recommend that NESDIS and NWS work together to form a sustained team to routinely and proactively (1) document and present impacts, including from the science and socio-economic perspective, (2) look at NWP and other Earth System Applications for RFI impact assessments, (3) look at fundamental information content and the potential loss of critical capabilities, (4) evaluate impacts from an engineering and science perspectives, (5) provide recommendations to NESDIS and NOAA on ways to protect the bands, (6) determine the thresholds for acceptable contamination, by band, (7) monitor the potential effects of RFI on Radio Occultation (RO) measurements, (8) establish user engagements to assess and communicate impacts to all users (beyond NOAA), (9) coordinate with other teams and other agencies that are assessing RFI impacts
    - **#2** We recommend establishing/expanding contacts with the NTIA and FCC via ACIO-S at the technical level, perhaps through invitations to speak in NOAA and to have technical dialog, to socialize (with NTIA and FCC) the technical impacts (on NOAA users, on society, etc) of these potential RFI contaminations.
    - **#3** We recommend NESDIS invest in ways to enhance its readiness for RFI resulting from new allocations and uses, including 5G and beyond. To better protect the ability to use microwave Earth observation data, we recommend that NESDIS improve monitoring of RFI including signal characteristics in order to find better ways to detect RFI, and improve the capability to simulate the impact of future RFI scenarios on the LEO observation fleet.
    - **#4** We recommend NESDIS seek enhancements to future microwave sensor designs that improve their ability to more readily assess RFI contamination. In particular, hyperspectral microwave sensing is a technology that should be considered for future architecture planning. In particular, we note that the Joint Venture Partnership program in NESDIS is currently funding hyperspectral microwave sensing studies and we recommend sustaining such studies.

Background:

The effects of Fifth Generation (5G) wireless transmission can degrade passive microwave observations , and poses a risk to corrupt atmospheric temperature and moisture sounding data critical to Numerical Weather Prediction. Detection algorithms may allow radio frequency (RF) contamination to be identified and contaminated data to be flagged for non-use. In addition to 5G communications, other sources of contamination may include aircraft and spacecraft communications, radars, and terrestrial mobile communications (e.g., ships, aircraft, etc.). 5G RFI is currently over more populated areas and the signal can vary over the course of a day and even over the business week as people use downtown areas for work purposes during the daytime and personal purposes in other locations in the evenings.

Sources of RFI contamination might be identified by using spatial, temporal, statistical, spectral or other algorithms. Once contamination is found, actions include flagging the data not to be used, mapping areas of

contamination, determining the impact on numerical weather prediction (NWP), exploring the use of higher frequencies, and regularly assessing product performance and modifying products to make maximum use of the Earth observation data.

Facts, Results and Findings:

The SAT discussions centered around interference caused by radio frequency interference (RFI), including the statement of the issue and possible mitigation strategies.

- RFI is a risk for all passive environmental microwave sensors in multiple spectrum bands.
- RFI is a global issue.
- There is a risk that forecasts become less accurate as the levels of RFI increases spectrally and spatially. Forecasts have not yet begun to degrade, and the expansion of 5G is still beginning. 5G communications are expanded globally and 6G is developed, the RFI issue could have a larger and degrading impact on NOAA systems and forecasts.
- When determining sensor designs for 10-15 years in the future, the degradation needs to be taken into account with the understanding that RFI is an evolving impact. NOAA should consider addressing RFI interference for all future passive microwave sensor applications.
- The ATMS sensor is a 20-year old design and does not include the necessary capability for RFI detection. Some preliminary work on 5G RFI detection has started. RFI detection capabilities are needed both on-orbit and through ground-based methods.
- RFI can ultimately lead to loss of life and property because of degraded forecasts. The location, time, and strength of the RFI are all needed to be known to understand the impact on NWP. Therefore realistic and validated RFI simulation tools are important to develop. It is likely that applications other than NWP may also be impacted by degraded microwave sensing in the environmental bands.
- In the beginning, it is possible that being exposed to RFI will force NOAA to develop a different quality control mechanism (in the NWP context for example) in order to detect and remove the impacted data. But the hard-to-predict spatial, vertical and spectral extents and the intensity of the contamination, all make this RFI a threat to our very ability to measure the Environment globally.