FCC Comment for ET Docket No. 16-191 by Gary R. Olhoeft, PhD, Professor Emeritus, CSM

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The FCC Office of Engineering and Technology Technical Advisory Council has requested comment on a variety of issues related to radio spectrum noise and changes to the spectrum noise floor over the last 20 years.

It specifically requests answers to questions concerning a variety of sources of anthropogenic device noise, "Noise denotes unwanted radiofrequency (RF) energy from man-made sources." In this limited context, it ignores the highly variable natural sources of noise from the magnetic and electrical fields of the Earth, sun, solar wind and their mutual interactions, as well as the interactions between devices and the Earth's surface, atmosphere and natural field processes. It also ignores changes that occur with time such as the solar sunspot cycle, or corrosion of earth grounding systems, but also as the devices themselves age (for example, allowable microwave oven leakage is only specified at the sale of a new device.)

Variations in the Earth's natural magnetic field amplitude and orientation have been recorded at low frequencies by magnetic observatories around the world since 720 AD in China and about 1510 in Europe (more details may be found in Merrill and others, 1996; see also Krider and Roble, 1986, Kelley, 2013). See Figure 1 for an example. Magnetic observatories are operated around the world by a variety of organizations (in the US by the USGS and NOAA) and coordinated by INTERMAGNET (http://www.intermagnet.org). Few magnetic observatories also record electric fields, and fewer still record continuous spectra into the radiofrequency range (Figures 2 and 3). One example that does so is the National Radio Quiet Zone for radioastronomy (https://science.nrao.edu/facilities/gbt/interference-protection/nrqz). See also http://www.its.bldrdoc.gov/resources/table-mountain/tm-home.aspx. There are now over 100 radioastronomy quiet zones around the world: https://www.google.com/maps/d/viewer?mid=1HX_7mIUcmDybmsONe9hJGisMOhc&hl=en). These magnetic observatories also monitor (along with NASA and NOAA satellites) solar magnetic and radio storms that impact commercial FAA and U.S. Air Force air traffic control operations (http://www.spaceweather.com), and interfere with GPS, pager, cellular systems, and the power grid (Centra Technology Inc., 2011).

I would also note that since the 1950's, the USGS has mapped soil properties (see Figure 4) for the FCC to better site radio stations. These are also used by the U.S. Navy and U.S. Coast Guard to better locate LORAN and submarine communications facilities. The USGS has also been asked to explain why transmitter antenna patterns change with varying water table depth, changing snow or permafrost conditions, and other environmental parameters. Much of this data is hard to find as many subject matter experts are retired.

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In addition to my comments above, here are my answers to the questions posed along with a few added questions that should have been asked, but were not. My answers are in **bold** brackets.

1. Is there a noise problem? **[Yes, but it depends upon how you define "noise." I would not limit the sources of noise to man-made devices.]**

a. If so, what are the expected major sources of noise that are of concern?

[Just about anything electrical, including RFID, electronic inventory control systems, WiFi, smart meters, remote control drones, cell phones and base stations, automated vehicle systems, robots, lighting systems, arc welders, security devices, lightning, solar storms, large single point transmitters, distributed transmitting systems, electric transit systems, wireless charging and power transmission systems.]

b. What services are being most impacted by a rising spectrum noise floor?

[Function of medical implants (including cardiac pacemakers and neurostimulators), geophysical instruments used for infrastructure location and characterization, agricultural crop and soil moisture monitors, resource exploration, geolocation services, automated systems (vehicles, robots, drones).]

c. If incidental radiators are a concern, what sorts of government, industry, and civil society efforts might be appropriate to ameliorate the noise they produce?

[Allow as little as possible RF through the air. Instead use underground shielded conduits, fiber optics, point to point LiFi, UWB low power pulses. Use shielding, ferrites and filters to isolate homes and schools. Ban transmitters inside vehicles, schools and homes. Require FDA certification (the FDA covers a wider range of frequencies than the FCC) for new technologies.]

2. Where does the problem exist?

a. Spectrally

i. What frequency bands are of the most interest?

[All, below 1 Hz to above 10 GHZ]

b. Spatially

i. Indoors vs outdoors? **[Both, and also in or near vehicles. Buildings or elevators may act as waveguides, enhancing the effects (multipathing and waveguide effects have also been reported from natural geological structures.) Corroding grounds and grounding systems struck by lightning change noise with time requiring periodic noise re-surveys.]**

ii. Cities vs rural settings? **[Both, with earth-ionosphere waveguide enhancement, and topographic and building multipathing.]**

iii. How close in proximity to incidental radiators or other noise sources?

[Depends upon wavelength and sensitivity, amplitude and duration.]

iv. How can natural propagation effects be accounted for in a noise study?

[Modeling, and better models are needed, including better descriptions of properties and processes in soils, ecosystems, buildings, streets, infrastructure.]

c. Temporally?

i. Night vs day? **[associated changes in ionosphere, soil and atmospheric moisture]**

ii. Seasonally? **[see below]**

[iii. Soil type? Moisture content? Thawed vs frozen? Bare soil and rock vs plant vs asphalt and concrete covered? Surface and volumetric roughness? Frequency dependence? Magnetic soil or rock? Corroding earth grounds changing with time? Nonlinear effects? Evapotranspiration?]

3. Is there quantitative evidence of the overall increase in the total integrated noise floor across various segments of the radio frequency spectrum? **[Yes.]**

a. At what levels does the noise floor cause harmful interference to particular radio services? **[Varies with service and location.]**
[Does this include NRAO and biological/ecosystem effects?]

b. What RF environment data from the past 20 years is available, showing the contribution of the major sources of noise? **[USGS, NOAA, NASA solar wind.][NRAO NRQZ NIST][World Data Centers][Some data go back to the 1950's, but high quality RF data only exist since 1980.]**

c. Please provide references to scholarly articles or other sources of spectrum noise measurements. **[Representative references are given below at end.]**

4. How should a noise study be performed? **[Many answers depend on how you define "noise"; a few representative answers are given.]**

a. What should be the focus of the noise study? **[See USAF, 2009, and Gruber, 2010; and emissions from newest technology such as robotic vehicles that might interfere with each other.]**

b. How should it be funded? **[Non-regulatory government agency.]**

c. What methods should be used? **[Holloway and others, 2001.]**

d. How should the noise be measured? **[Tensor electric and magnetic fields vs frequency in continuous observatory recordings.][Use multiple locations as water tables move, seasons change, etc.]**

i. What is the optimal instrumentation that should be used? **[Spectrum analyzers and transmit-receiver path characterization as in Holloway and others, 2001; Labson and others, 1985; referenced against properly shielded rooms.]**

ii. What measurement parameters should be used for that instrumentation?

iii. At what spatial and temporal scales should noise be measured?

iv. Should the monitoring instrumentation be capable of determining the directions of the noise sources? If so, how would those data be used? **[Yes; to determine sources and backtrack source and path location and characteristics for modeling to other situations or locations.]**

v. Is there an optimal height above ground for measurements? **[Varies; some should be underground or inside buildings.]**

e. What measurement accuracy is needed?

i. What are the statistical requirements for sufficient data?

ii. Can measurements from uncalibrated, or minimally calibrated, devices be combined?

iii. Is it possible to "crowd source" a noise study?

f. Would receiver noise measurements commonly logged by certain users (e.g., radio astronomers, cellular, and broadcast auxiliary licensees) be available and useful for noise floor studies? **[Yes] [NRQZ] [ARRL?]**

g. How much data must be collected to reach a conclusion? **[Several solar sunspot cycles.]**

h. How can noise be distinguished from signals? **[Depends on definition of "signal" vs "noise".]**

i. Can noise be characterized and its source identified?**[Yes]**

ii. Is there a threshold level, below which measurements should be ignored?
[See Figure 2]

References (representative, not comprehensive, insufficient time to collect more)

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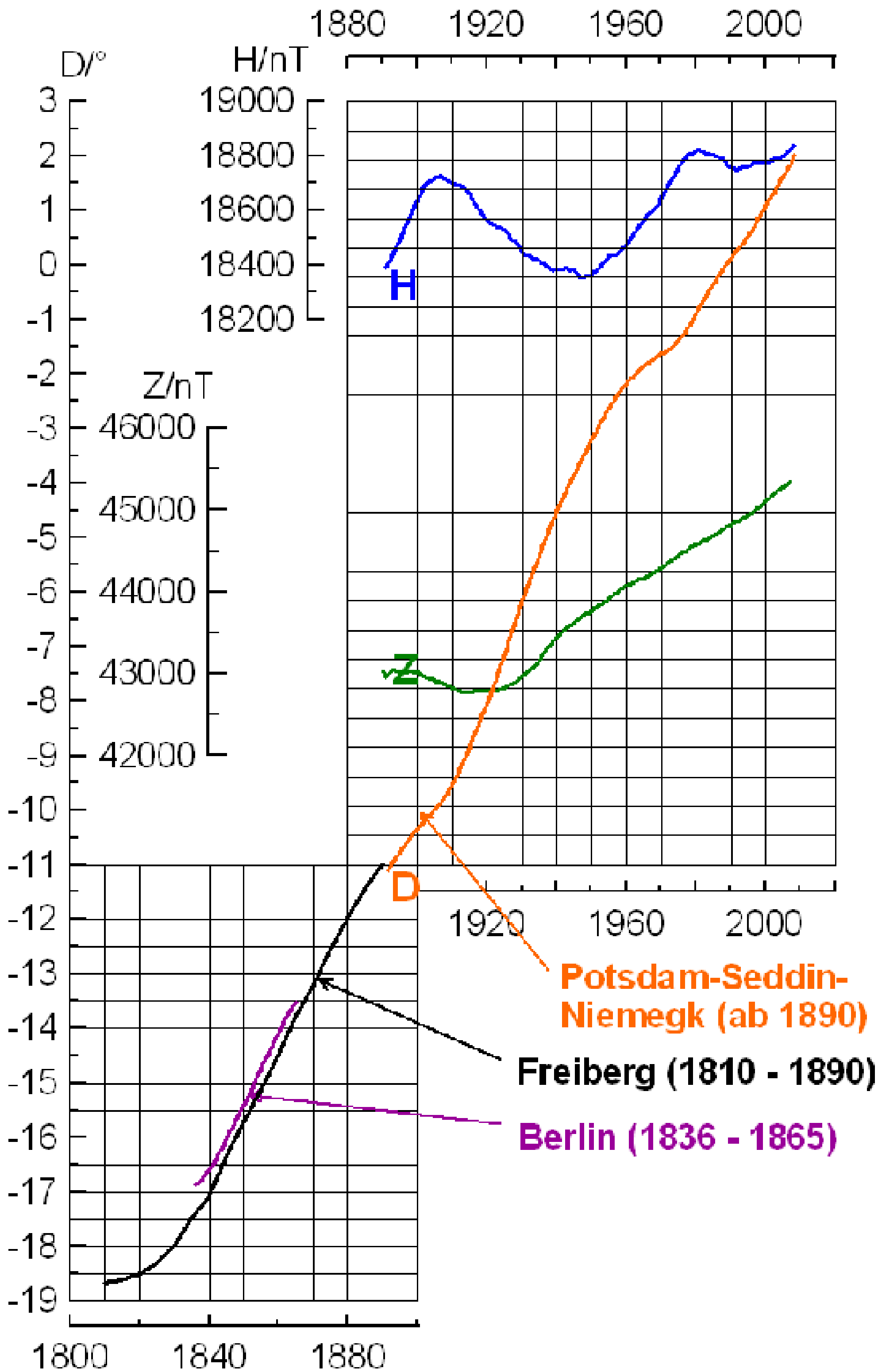

Figure 1 An example of the Earth's changing magnetic field versus time recorded at German observatories. H is horizontal field amplitude, Z is vertical field amplitude, and D is declination. This is low frequency (below 1 Hz) data, higher frequencies were not recorded until the 1950's.

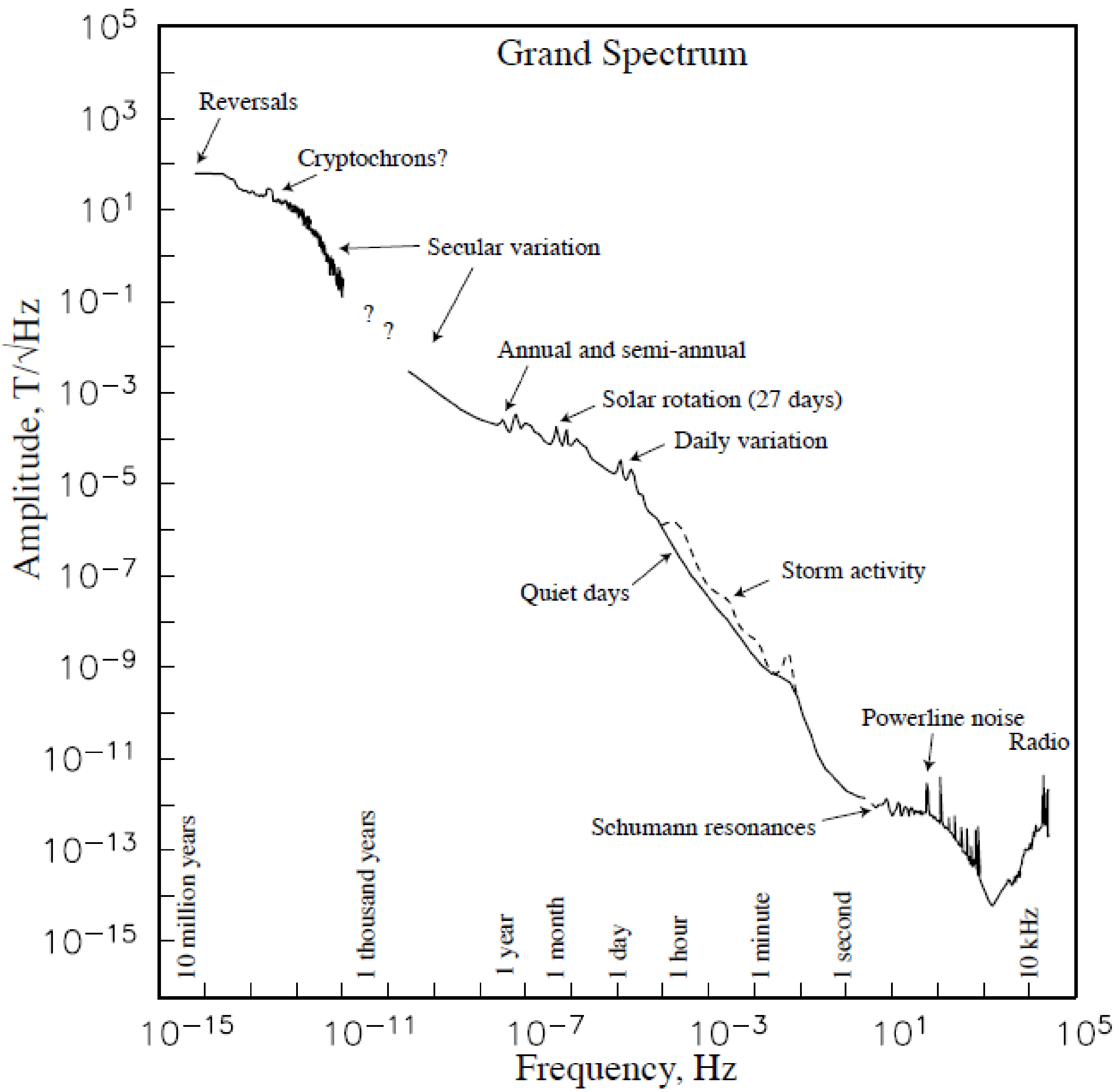

Figure 2 An example composite amplitude spectrum of geomagnetic variations (Constable and Constable, 2004) with annotations indicating the various physical processes from the earth, sun and solar wind interactions. Note the higher frequencies are dominated by man-made sources.

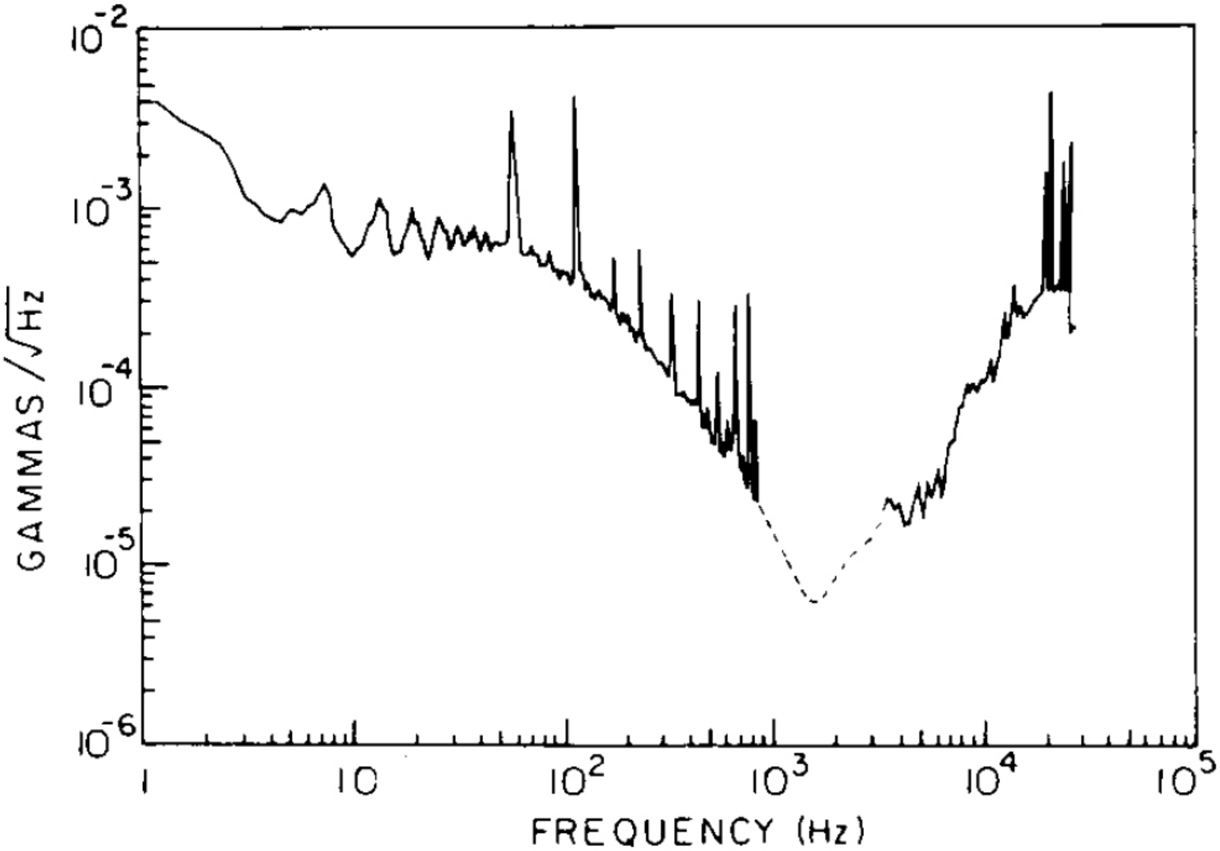

Figure 3 Expanding highest frequencies of Figure 2 (from Labson and others, 1985) to show the dominant effects of powerline and radiofrequencies over natural noise sources. Note this figure changes with location, time of day, season, weather, soil properties and other factors. The original caption reads, “Typical summer spectrum at San Antonio Valley, California, July 14, 1980”.

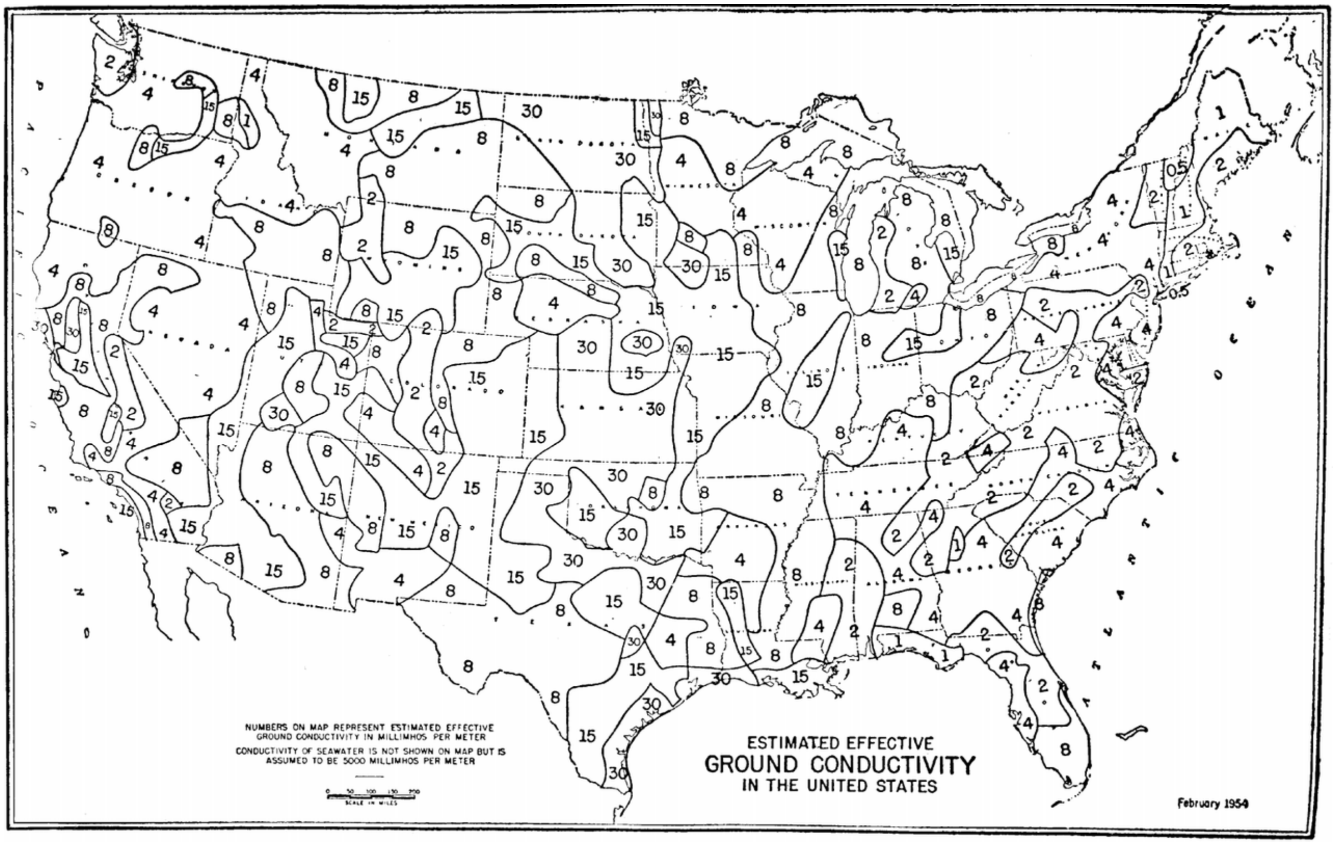

Figure 4 February 1954 FCC Ground conductivity map without regard to soil type, moisture content, temperature, seasonal variation, frequency dependence or other relevant factors, still in use today (accessed August 2016):
https://www.fcc.gov/media/radio/m3-ground-conductivity-map