Special Test Addendum

FCC Harmonic Emission Testing Sections 87.139 (a) and 2.1051

FCC Rule Section 87.139 requires that spurious emissions be tested through the fourth harmonic. Pursuant to FCC Rule Section 2.1051, these tests are typically performed at the transmitter output port with the antenna removed. However, in situations where it is impractical to remove the antenna, the tests are performed using radiated emissions.[1]

Echodyne's radar, which operates at a fundamental frequency of 24.45-24.65 GHz, is designed with its patented Metamaterial Electronic Scanning Array (MESA™) integrated with the transmitter. This antenna is completely bi-lateral and can be measured as a passive input/output device identical to the way a printed antenna with a single coax port would be tested. It does not have transmitter power amplifiers or a receiver low noise amplifier in the path of antenna. Because the MESA antenna is embedded in the radar, it is not practical to remove the antenna to conduct compliance testing. Thus, pursuant to the referenced FCC and NTIA guidance, spurious emissions were tested using radiated measurements.

Table 1 – Radar Harmonic Verification

Harmonic	Frequency
Fundamental	24.45 – 24.65 GHz
2	48.90 – 49.30 GHz
3	73.35 – 73.95 GHz
4	97.80 – 98.60 GHz

The DUT spurious emissions were tested by fixing the beam to boresight while the test engineer moved the table around to find the peak radiated emission at each harmonic frequency while the radar was transmitting the standard waveform. To accommodate the spectrum analyzer maximum frequency of 40GHz, specific waveguide down converter mixers and horn antennae were utilized to measure the free space emissions at a fixed distance from the DUT.

As stated above, the FCC spurious emission limits are specified at the transmitter port. Thus, the radiated measurements must be corrected back to the virtual transmitter port to confirm compliance with FCC limits. The correction is done using known calibration gain/loss factors, including cable loss, mixer conversion loss, antenna gain and free space loss to the DUT.[2]

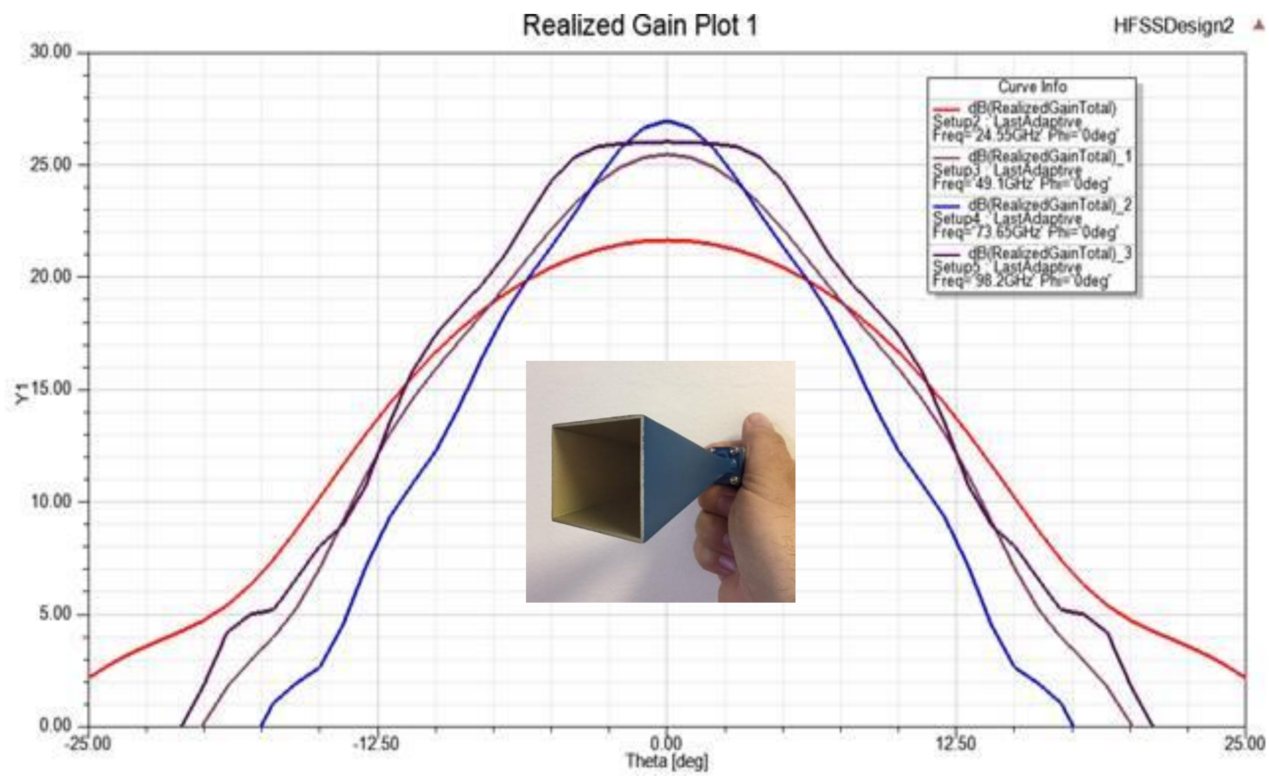
For the antenna gain correction, we used the known fundamental frequency antenna gain of 21 dBi as the correction factor. We used the fundamental gain rather than the harmonic gain because it is not possible to directly measure or model gain at the harmonic frequencies due to the complexity of the MESA antenna and the millimeter wave frequencies involved. However, fundamental gain will typically be less than harmonic gain, so using it in the calculations results in a more conservative (i.e. lesser) correction factor, thus overstating the

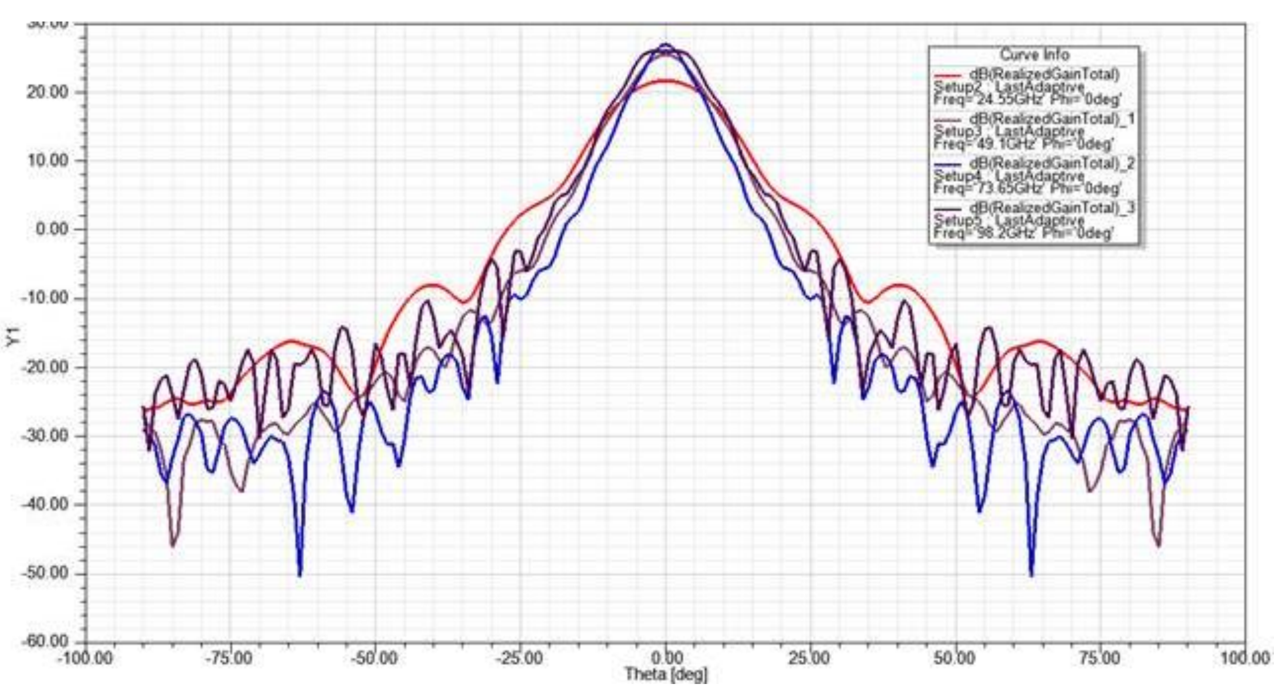
[1] See Section 5.8 of KDB Publication 971168 D01 (hyperlink) "Measurement Guidance for Certification of Licensed Digital Transmitters". Footnote 6 of the KDB Publication states that "radiated measurements may be acceptable for some integral-antenna devices for Sections 2.1046 and 2.1051 compliance purposes". See also NTIA Report TR-05-420 (hyperlink) "Measurement Procedures for the Radar Spectrum Engineering Criteria (RSEC)". In Section 5.2 "Measurement Point (Hardline vs Radiated)", the NTIA Report recommends performing compliance measurements on radiated emissions.

[2] See Section 5.8.4 of the KDB Publication and Section 2.3.2 of the NTIA Report.

emissions at the antenna port. In other words, a transmitter that meets the spurious emissions limits using fundamental gain as the correction factor would meet the limits with an even larger margin if harmonic gain were used.

The following simulation of a standard horn antenna demonstrates the fundamental principle that antenna gain increases at higher frequencies given a fixed geometry.





As can be seen in these plots for the standard waveguide horn antenna, the gain at the harmonic frequencies is greater than the fundamental gain of the 24 GHz reference horn antenna. This horn antenna was chosen as a simulation surrogate due to its nominal gain being similar to the nominal gain of the MESA antenna. We are not proposing to use these plots for the harmonic gain correction back to the transmitter point, but rather to show that it is conservative to use the known fundamental gain of the MESA antenna for corrections.

Because the MESA antenna has a known gain of 21 dBi, NEMKO used this value during its testing to correct the radiated power back to the antenna port.

$$Pwr_{Antenna} = EIRP(dBm) - Gain(dBi)$$

Using the assumptions and test principles described above, the radar clearly complies with the requirements of FCC Rule Section 87.139(a).