Using RoofView® 5 to Simulate 5G Beam Forming Antennas

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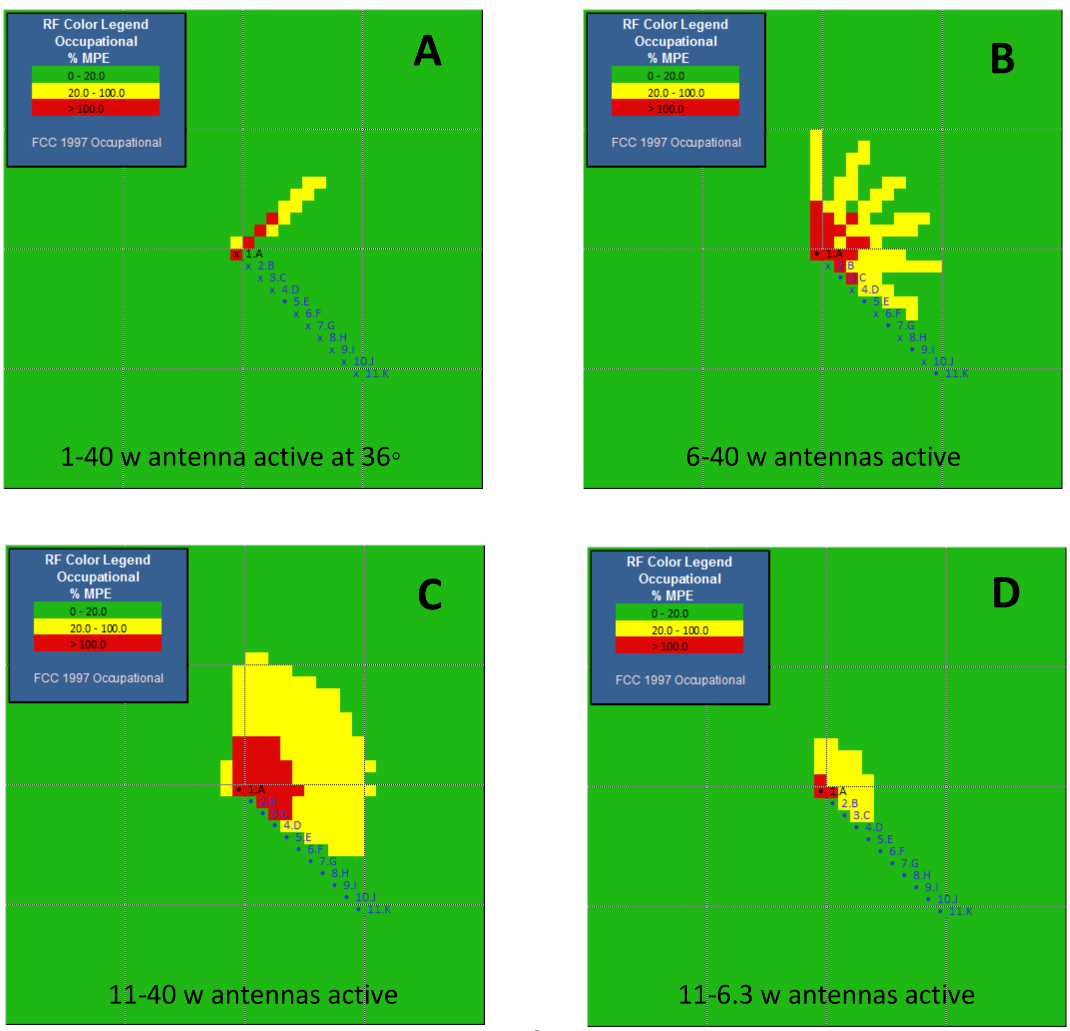
An important aspect of 5G technology is the use of beam forming antennas. Beam forming antennas, rather than radiating the antenna input power continuously throughout a sector with a beam width of, say, 65 degrees, create much narrower beams that are directed toward individual users connected through a given cell site. The antennas can support multiple, simultaneous beams oriented in different directions to serve different mobile customers. The total antenna input power is distributed among the various beams with less power available for a given beam depending on the number of simultaneous beams at any given time. If a single mobile user is being served, more power will be available for that beam but if, say, 4 mobile users are being simultaneously being served, the total power will be distributed in some fashion among those four beams. Further, and very importantly, these individual beams track the mobile user such that they are often constantly moving with the result that the power density at a given point in the vicinity of the antenna installation varies in time. Hence, if you were to be able to monitor the local power density at a particular location, it would vary in magnitude since (a) the momentary instantaneous signal level can change depending on how well the mobile user's signal is being received at the cell site, the available power at any given moment depends on the number of beams being radiated by the antenna due to the requirement of multiple mobile users and (c) the beam can be moving in time in order to track the user.

The above described factors mean that there is no possible way for any simulation tool, such as RoofView®, to model the RF field magnitude for a given point at any specific time; this is because there is simply no way to know what the base station computer processing is going to cause the radiated RF beam(s) from the antenna to do in terms of beam direction and radiated power within a given beam. The time-averaged power density at a given point becomes a statistical matter based on the above factors.

Various researchers are now examining this statistical nature of the radiated signals from beam forming antennas. Naturally, because it is not possible to predict the number of beams being produced at any given time (which depends on the number users at the time) nor the beam pointing directions, the statistical variation in received power density at a point in the vicinity of the beam forming antenna can vary over a fairly large range. It becomes relevant to think in terms of the signal duty cycle at any specific point within the beam scanning range of the antenna. Despite this challenge to calculating the RF field power densities produced by beam forming antennas, it is possible to estimate time-averaged values of the fields. Based on technical reports focused on this matter, duty cycle values for active beam forming antenna cell sites in the range of -6.6 to -11.6 dB have been reported from normally operating beam forming antennas (1). A value of approximately -8 dB has been reported as the 95th percentile value of duty cycle resulting from a detailed analysis of simulated traffic associated with a beam forming antenna used in a range of both macro and micro communication environments (2). It is noted that IEC 62232:2017 (3) specifies that the 95th percentile value is sufficient for defining the "actual maximum exposure condition". The following description explains how RoofView® can be used to produce estimates of time-averaged RF fields associated with beam forming antennas.

In this example, RoofView® is used to simulate a single 120° sector of a 2 ft by 2 ft beam forming panel antenna wherein the antenna produces narrow 12° beamwidth beams that can be directed to individual users. The graphic images in the panels below illustrate the process. A total of 11 antennas, each with a beam width of 12° are positioned at the same coordinates x, y. Each antenna is sequenced at successively greater azimuths spaced by 12 degrees. Each antenna is assumed to have an input power of 40 watts.

Panel A illustrates the calculated RF fields expressed as a percentage of the FCC occupational MPE for a 5G 37 GHz antenna for a single beam oriented at 36 degrees (only one of the 11 antennas is turned on). Panel B illustrates the RF fields for six of the antennas being turned on. Finally, panel C shows the result when all of the antennas are turned on. The point of this illustration is to indicate that at any given instantaneous point in time and a given point in space, the RF field will be the result of a single beam that happens to be pointed toward that location. In other words, the RoofView® plots show that if only a single beam were to be present and <u>stationary</u>, the RF field values in each RoofView® pixel would be as illustrated.



Panel C, however, is fictitious in that it is illustrating an envelope of what the composite RF field at any given point throughout the 120° sector of the antenna would be if all 11 beams were each radiating 40 watts. In reality, with multiple beams in operation, the average power available for any individual beam will be reduced by the duty cycle of the beams. In this example, a beam duty cycle of -8 dB has been assumed (remember, the duty cycle depends on all of the things discussed above and it is not possible to know an exact value). Panel D illustrates the result of operating all 11 antennas (beams) with only 6.3 watts delivered to each antenna (beam) (-8 dB relative to the 40 watts delivered by the transmitter for an -8 dB beam duty cycle). Thus, panel D provides what the estimated time-averaged RF fields will be in each RoofView® pixel and it is apparent that the region of concern for compliance with the FCC MPEs has diminished significantly. Note that the antenna (beam) input power of 6.3 watts is significantly less than the 40 watt transmitter power but when multiplied by the number of possible beams used in this example exceeds the transmitter power (11 × 6.3 = 69 watts). This apparent discrepancy results from (a) the requirement to ensure that the time-averaged power used in RoofView®, that is radiated on any beam, is 8 dB less than that were a single beam, conventional antenna being used and (b) the number of beams that are presumed to exist for the antenna. If the total number of beams possible from the antenna is, say, 6, the input power for each must still comply with the -8 dB duty cycle of the beams in association with the 40 watt transmitter (hence, the power will be the same 6.3 watts for this example) but the apparent total power will now be less than the 40 watt transmitter output. The crucial factor is to allocate the correct time-averaged power, based on beam duty cycle, to each potential beam.

In summary, the only thing that we can say is that the duty cycle averaged value of power density at a given specific point in space will be substantially less than were the antenna a conventional fixed beam type panel array. Also, one final comment relative to conservatism: since RoofView® sums the RF field power densities from all possible beams in each calculation pixel, the illustrated region shown in panel D above is likely somewhat an over estimate. This results because in the RoofView® calculation process, the software assumes that each beam is constantly present and, hence, RF fields adjacent to each beam get summed in each pixel. This factor, however, will result in a conservative estimate of the extent of RF fields near the antenna. In the above example, the RF field at specific points in the vicinity of the antenna were found to be approximately 1.4 dB greater in calculated field with all beams active as opposed to just a single beam pointing at the same direction. Finally, the result is obviously dependent on the assumed duty cycle that the beam forming antenna beams actually present when in use and the time duration over which the duty cycle has been determined.

In practice, a suggested approach for modeling beam forming antennas with RoofView® includes the following: (a) Decide on an appropriate beam duty cycle value (nominally -8 dB reported in (2) represented the 95th percentile value for the simulations reported); (b) use the azimuth beam width specified for the antenna; (c) allocate a number of beams, as though they are individual antennas on the AntennaData sheet, equal to the total number of beams supported by the antenna and distribute their pointing directions uniformly across the sector (this will allow for creating an envelope of the RF field contours across the sector); (d) assign an antenna (beam) input power equal to the transmitter output power multiplied by the duty cycle value (for example, a duty cycle of -8 dB is equivalent to a numerical value of 0.16); (e) set the multiplier value in RoofView® [use the **Mult ×** button on the control panel]

equal to the numerical value of the duty cycle (in the example, 0.16) and hit **Recalc Area** to get the analysis result.

NOTE: The simulation of narrow beams less than 30 degrees in azimuth beamwidth cannot be accurately performed in earlier versions of RoofView® such as versions 4.15 and earlier. Version 5 of RoofView®, however, allows for beam widths down to 6 degrees for simulating narrow beam forming antennas.

1. Thors B, Furuskär A, Colombi D and Törnevik C (2017). Time-Averaged Realistic Maximum Power Levels for the Assessment of Radio Frequency Exposure for 5G Radio Base Stations Using Massive MIMO. IEEE Access, Vol 5, pp. 19711-19719.

2. Baracca P, Weber A, Thorsten W and Grangeat C (2018). A statistical approach for RF exposure compliance boundary assessment in massive MIMO systems. WSA 2018; 22nd International ITG Workshop on Smart Antennas. 14 June 2018, Bochum, Germany. Print ISBN: 978-3-8007-4541-8. https://arxiv.org/abs/1801.08351

3. IEC (2017). Determination of RF Field Strength and SAR in the Vicinity of Radio Communication Base Stations for the Purpose of Evaluating Human Exposure. IEC Standard IEC 52232:2017, August 2017.