Safety distances for small HF loop antennas

The RF fields near small HF transmitting loops can be surprisingly strong. Even at remarkably low operating power they may exceed safe exposure limits.

You can use a simple formula to calculate safety distances for most amateur radio antennas, but this calculation underestimates the safe distances for loops [1] [2] [3]. So, I used an NEC antenna model to calculate near fields around a small loop and compared them to safety limits.

A safety distance extends to the farthest point from the loop where the RF field strength is at the limit allowed by safety standards. In the UK, RF exposure limits are set by the Health Protection Agency based on standards developed by the International Commission for Non-Ionizing Radiation Protection (ICNIRP) [4]. An ICNIRP project group is revising the HF standards and hopes to have the public consultation document out before the end of 2017 [5].

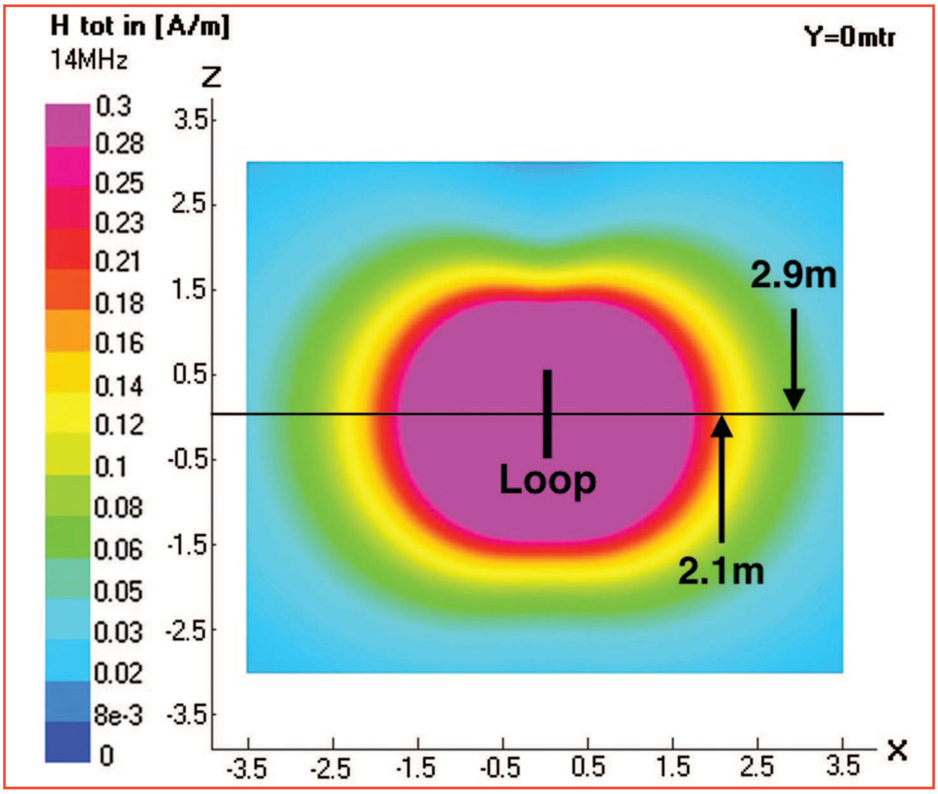

FIGURE 1: Contour plot of magnetic induction H for 10 watts at 14MHz. Occupational and public safety distances are indicated on the perpendicular axis of the loop.

Average Power

RF exposure limits depend on the average power into the antenna, taking into account the duty cycle of the mode, Tx/Rx time and transmission line losses. The Tx/Rx time is the worst-case percentage of time you are on the air in any six-minute period. Usually, it's advisable to assume 100% transmit time to allow for a long transmission. For example, conversational CW (40% mode duty cycle) with 10 watts peak power, 100% transmit time, and no line loss, has an estimated average power of 4 watts.

My NEC calculations account for the power lost because of resistance in the copper loop. They do not include losses in the capacitor and in the ground beneath the loop, both of which can be significant. These losses, which depend on the loop construction and location, lower the antenna Q and the field strengths. Excluding them is a conservative assumption that increases safety distances.

NEC model

The most popular type of small loop for amateur radio is a vertical loop with a tuning capacitor connected across a gap in the conductor. Changing frequency involves adjusting the capacitor for maximum received noise and then fine-tuning for best SWR while transmitting with low power.

The NEC model is for a 1 metre diameter loop of 10mm copper tubing in free space. To account for the effect of ground currents induced by the near fields, I increased the input power in the calculations by the factor 2.56 used in US FCC safety distance calculations [1] [2]. This conservative assumption corresponds to a near field factor of 1.6.

Dr Kai Siwiak, KE4PT, sent some examples of FCC safety distances he calculated using analytic formulas for the near fields [6]. These served as a gold standard for checking the accuracy of the NEC model.

Safety distances

Table 1 shows calculated ICNIRP safety distances when the loop is fed with 10 watts average power. Distances are measured from the centre of the loop. Occupational exposure limits apply to amateur radio operators, whereas lower limits apply in General Public areas.

Tables 2 and 3 are for average power of 100 watts and 400 watts, respectively.

While the *far field* pattern has nulls in both directions along the loop axis perpendicular to the plane of the loop, there are strong *near* fields on the axis. Almost all of the distances in the tables are determined by the RF magnetic field on the perpendicular axis. In a few cases (indicated in the tables) electric fields around the tuning gap determine the most conservative safety distance [7].

Figure 1 is a *4nec2* program contour plot of total magnetic induction H [A/m] for 10 watts average power at 14MHz. The occupational safety distance (2.1 m) and the public distance (2.9 m) are indicated on the perpendicular axis of the loop.

Low power operation

Safety distances move closer to the loop as you lower the power, but not as much as you might expect. Tables 1 and 2 show that occupational safety distances at 10 watts are around 60% of the 100 watt distances, although that's only 10% of the power.

Kai Siwiak, KE4PT warns about over-exposure to RF from a pedestrian mobile or backpack loop **[8]**: "Because this is not a case of 'whole body' exposure to a plane wave field, we would need to measure the specific absorption rate (SAR) to determine compliance. As a matter of interest, however, if the head is 10cm in front of, and in line with, the loop conductor, power levels of just 7.6mW, 7.2mW, 14mW and 27mW at 7, 14, 21, and 28MHz respectively will immerse the whole head, neck, and upper torso in magnetic field at a level that exceeds the far-field whole body limit." His figures are based on FCC standards. The ICNIRP safety standards are generally more conservative [3], so the power limits in that case are even lower.

Other hazards

The RF magnetic fields from small loops can induce significant currents in conductors. Also, small loops can couple strongly to nearby ferromagnetic materials that concentrate RF magnetic field lines, making the field stronger.

The ICNIRP guidelines include warnings about sparks, shocks, and burns from induced currents. Other possible risks include interference with cardiac pacemakers, detonation of electro-explosive devices (detonators) and ignition of flammable materials [4].

Conclusions

Intense reactive near fields surround a small transmitting loop in all directions. Even at low power the near-fields exceed the ICNIRP maximum permissible exposures. The RF magnetic field is usually strongest along the axis perpendicular to the loop. Depending on the power and frequency, safety distances are sometimes determined by strong electric fields in the region above the tuning gap.

W1RFI, author of *RF Exposure and You*, advises amateurs to err on the side of caution when they establish safety perimeters around antennas [2].

Acknowledgment

My thanks to Kai Siwiak, KE4PT, for very helpful answers to my questions.

References

[1] Evaluating Compliance with FCC Guidelines for Human Exposure to Radiofrequency Electromagnetic Fields, *OET Bulletin 65b* (1977). Accessible at https://transition.fcc.gov/bureaus/oet/info/documents/bulletins/oet65/oet65b.pdf

[2] *RF Exposure and You,* Ed Hare, W1RFI, ARRL, 1998

[3] RF Exposure Safety with HF Antennas, P DeNeef, AE7PD, *RadCom* September 2015

[4] ICNIRP Guidelines for Limiting Exposure to Time-Varying Electric, Magnetic, and Electromagnetic Fields, *Health Physics* 74(4) 494-522 1998. Accessible at www.icnirp.org/cms/upload/publications/ICNIRPemfgdl.pdf

[5] Email, February 27, 2017, R Croft, Chairman of the ICNIRP project group revising HF guidelines. Updates are posted at www.icnirp.org.

[6] *Radiowave Propagation and Antennas for Personal Communications,* K Siwiak and Y Bahreini, Artech House, Norwood MA 2007

[7] Ionospherica, K Siwiak, KE4PT, *The QRP Quarterly* Fall 2014, accessible at www.qsl.net/k4fk/presentations/QQ1014_24-25-Siwiak-Ionospherica-IV-Loop-nearfield.pdf

[8] Technical correspondence, K Siwiak, KE4PT, *QST* March 2012

TABLE 1: ICNIRP safety distances for a 1.0m loop with P = 10 watts.

Frequency	Occupational safety distance	General Public safety distance
7MHz	2.1m	2.9m
14MHz	2.1m	2.9m
18MHz	1.9m	2.7m
21MHz	1.8m	2.5m
28MHz	1.5m	2.1m

TABLE 2: ICNIRP safety distances for a 1.0m loop with P = 100 watts.

Frequency	Occupational safety distance	General Public safety distance
7MHz	3.3m	4.3m
14MHz	3.4m	4.7m
18MHz	3.1m	4.4m
21MHz	2.9m	4.2m
28MHz	2.5m	3.9m*

*Electric field limit

TABLE 3: ICNIRP safety distances for a 1.0m loop with P = 400 watts.

Frequency	Occupational safety distance	General Public safety distance
7MHz	4.2m	5.7m
14MHz	4.5m	6.5m
18MHz	4.2m	6.9m*
21MHz	4.0m	7.1m*
28MHz	3.7m*	7.3m*

*Electric field limit

Dr Peter DeNeef, AE7PD
HamRadioAndVision@gmail.com

Feature

Why not write for *RadCom*?

We welcome all sorts of articles – technical or features – from established or brand-new writers. There's nothing quite like seeing your name in print for the first time! And, best of all, we pay for the articles we publish.

It has never been easier to share your enthusiasm for your new project or favourite part of amateur radio, and getting your work published in *RadCom* or *RadCom Plus* might be easier than you think.

Timescales and practical notes

It's well worth phoning for a chat before starting so that we can talk about what you're thinking of doing. This is particularly important if your article is time-sensitive, eg about a forthcoming event. Publishing delays mean we normally need to agree feature articles at least three months before publication and receive the finished text two months before the cover date.

We can provide a lot of help with 'polishing' your work. We 'sub-edit' everything in the magazine (even the regular columns) and most drawings are re-drawn by our illustrator.

We need your text as a plain Word document, with illustrations sent separately. Information on sending photos and drawings is at http://tinyurl.com/RadComPix

Feature articles are often published quite quickly. Technical articles are 'peer reviewed' by a member of the Technical Panel, then published when space becomes available.

Contact us

We're always happy discuss possibilities and help any way we can. Call 01234 832 700, option 8, or email radcom@rsgb.org.uk