

Quick Reference Guide

to

Magnetic - Loop Antennas – Calculator

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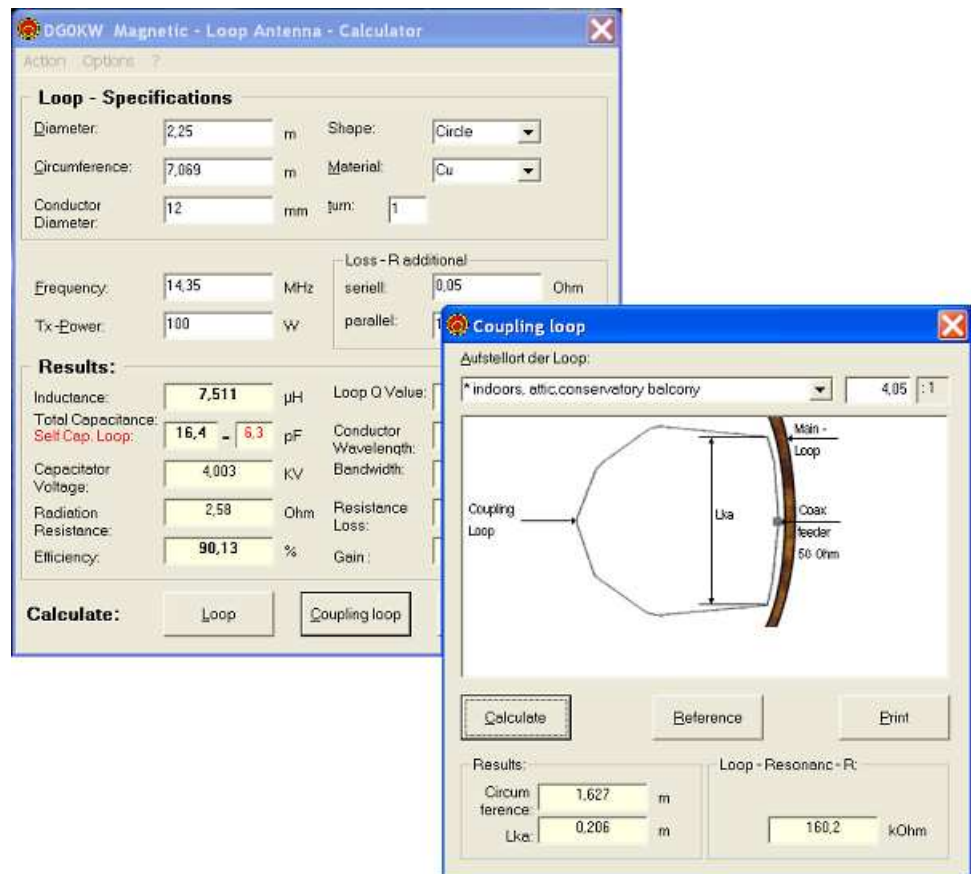


Abb.1 program view

- logical and manageable
- in Practically controlled Accuracy
- easy to handle
- quickly ready calculated antenna
- max. circumference 0.4λ

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1. Prerequisites

1.1 License Agreement

The problem associated with this License Software Product "Magnetic - Loop Antennas - Calculator" is for amateur radio applications freeware and is protected by copyright and other international treaties on intellectual property. A commercial use is only allowed with the permission of the author.

By installing, copying or otherwise using the Software Product, you agree to be bound by the terms of this EULA.

1.2 Warranty and Disclaimer

I do **not** guarantee the suitability of the program for a particular application or a specific hardware configuration.

Furthermore, I am UNDER NO CIRCUMSTANCES be liable for damages arising from the use or inability to use of this product. This includes the loss of business profits, the interruption of business operations, the loss of data and all other material and moral losses and consequential damage and applies even if I have been previously expressly advised of the possibility of such damages.

If an error is discovered, I am anxious to correct this as soon as possible.

BY USING THE SOFTWARE THIS EXPLAINS THE USER ACCEPTS THE ABOVE WARRANTY AND DISCLAIMER.

1.3 System Requirements

Hardware / Software - Requirements:

- Suitable each PC is with 80x86 processor from a 80486DX (and higher)
- Prozessor - the highest possible clock frequency (66 Mhz at min).
- 80x87-CoProzessor will be supported,
- min 16 MByte RAM (better > 32 MByte),
- a hard disk with at least 5 Mbytes of free memory
- VGA - Graphic card with minimum 800x600 pixels,
- VGA – Monitor,
- WINDOWS 9x and later or Windows NT, XP, W7 and successor,
- a program for viewing PDF - files.

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1.4 Usage

The *Magnetic-Loop-Antenna-Calculator* was developed to calculate magnetic loop antennas together with their rf feeding loop. It works up in the VHF range. The periphery / circumference ranges from $< 0.1 \lambda$ to about 0.4λ (Wavelength).

2. Installation

The software package does not need to be installed. It is designed in its structure so that it manages with the existing software on the PC. The ZIP - file is copied to a new folder and unpacked there.

If the program still make problems for you so please do not hesitate to contact the author.

3. Basics

3.1 Program start

You start the program "Magnetic - Loop Antennas - Calculator" by clicking on the MagnetLoop.exe in Explorer or via a corresponding shortcut on the desktop.

3.2 Structure of the Programme

The operation of the program happens via the keyboard and mouse click. This guarantees quick and comfortable working with the program. All program functions are accessible via the corresponding menus. The most important program functions can also directly activated via speed dialing keys (F - Keys or specific key combinations). Data will be entered in input masks with max. characters to be entered. For operation of the program simply use the keyboard or mouse click.

3.2.1 The menu bar

The second line of the window is called the menu bar with following dialog boxes: *Action*, *Options* and ? (which stands for the Help function)

3.2.2 The menu '*action*'

This menu contains the most frequently used functions of the "magnetic - loop antennas - computer" program. About '*Calculate*', the actual loop (loop) and the Ankoppelschleife for best adaptation transmitter / receiver to the Loop will be charged. By clicking '*Calculate*' the actual loop system will be calculated for ist best impedance matching to the load (receiver / transmitter) The last position in this menu are used for printing and ending the program.

3.2.3 The *Options* menu

Dieses Menü ermöglicht das Auswählen der Sprache.

3.2.4 The menu '?'

Use this menu to view the help text. Furthermore an '*Info*' – text provides you with a lot of useful information about the loop antenna in general and from the practical point of use.

3.2.5 key assignments

F1	Show Help
F2	Show info about the program
Strg + L :	Calculate the Loop (antenna)
Strg + A :	Calculate the coupling loop
Strg + D :	Print
Strg + X :	End of program

3.2.6 Print

Invoices can be printed with all entries. Window click on '*Print*' (or select '*Action / Print*' or Ctrl + D) - is given in each program. All calculated results together with their entries made can be printed by using the print button (or select '*Action / Print*' or Ctrl + D).

4. Guidelines for dealing with the Magnetic - Loop Antennas - Calculator

4.1 Abbreviations

Wdg.	turns
Tx	transmitter
R	resistor
C	Capacitor, capacity
Lka	Section of which the coupling loop lies close to the antenna loop
Drehko	variable capacitor

All other abbreviations are units.

4.2 entries

To his request - Magnetic - calculate loop antenna you have to enter some data, of course. Therefore it is necessary beforehand to have an concrete idea about the frequency range (from ... to), the data of the variable capacitor (initial and ultimate capacity, dielectric strength) as well as the maximum available space (diameter).

The following data must be entered: the diameter (or circumference), the shape (circle or square), the pipe diameter and the material the loop will be made of.

In case of there is no enough place for a one turn loop we are forced to change to a multi-turn one. In this case the loop becomes a coil. So we we have to enter the length of the coil which will be measured as the distance between the middle of the first winding to the middle of the last one. This of course includes the spacings between the individual turns.

The distance between two turns should not be too small because this increases the intrinsic capacitance of the loop. Furthermore and dependent of the transmitting power we may have spark-over voltages.

After entering the frequency, hf power and the choice of material we only have to push the "Calculate" button to display the results.

It can even loss resistors (in series, for example, to the variable capacitor - terminals) by soldering or clamping points or by losses in insulating materials (parallel), can arise, are entered. Changes to this resistance clearly show how some milliohms in series the efficiency of Magnetloop abate. The parallel loss resistance can also be artificially reduced by an additional resistor. This results in a wider bandwidth of the antenna. This may be for the receipt of certain signals of importance.

As we always have soldering- and or otherwise connecting points we have to be aware of losses. Those losses may be in the range of only milliohms however even the smallest loss will have a negative impact to our system. At our calculator I therefore implemented the possibility to input "Loss-R-additional" as serial as well as parallel resistor values.

Changing these values in the range of some serial-milliohms immediately will show the negative change of the loops efficiency. The impact of adding an additional resistor to the R-par will result in a wider bandwidth of the antenna. This may be of importance for certain weak signals at band ends.

Note:

The default values are an example of a loop working in the range 3.475 to 14.4 MHz with a variable capacitor ranging from 7.5 to 270 pF. As it turned out in practical use and for better performance I had to add a 3 pF fixed capacitor. As the practical construction of the loop showed the conductors 12 mm diameter was a bit too weak (copper pipe). A minimum diameter of 15 mm is recommended. The loop becomes slightly larger.

4.3 calculations

4.3.1 Calculation of Loop:

The calculation is started by clicking on 'Loop'. Following calculated values appear in the 'Results'.

The inductance of the loop, the loop loss, radiation resistance, the bandwidth, the maximum voltage across the capacitor, the efficiency and the gain of the loop. The latter has now been referred to a half - wave dipole of the same frequency in free space. A gain of -6 dBd in this case means that a signal received with this antenna has an 6 dB lower level referred to the above mentioned dipole (6 dB equivalent 1 S-unit). As a further result the capacitance values (C/pF) of the loop will be shown.

C variable capacitor = Ctotal - own capacity - Switching capacity (all in pF)

Following equation explains the relationship:

$$C_{\text{var}} = C_{\text{tot}} - C_{\text{intrinsic}} - C_{\text{circuit}} \quad [\text{pF}]$$

Since the self-capacitance of the loop is highly dependent on the mechanical structure of the loop, it is also difficult to calculate. The value calculated here can therefore be only an average figure. Reasonable results can be achieved for monoband loops operating on their characteristic resonance and without a variable -C. Finetuning if necessary can be made by varying the gap between the turns as well as overlapping of turns. (for example, 1.1 or 2.1 Wdg).

Not can calculate the switching capacity. This depends on the mechanical structure (spec on Drehko - . Port), but also on the spatial environment of the Loop (distance to house walls, trees, soil, cables, etc.). The switching capacity is a building under VHF - criteria from 3 - 10 pF, only wild construction is possibly greater.

As circuit capacitances can not be calculated beforehand a value (under vhf criteria) of about 3 to 10 pF should be taken into consideration. Other reasons for this imponderability are coming from the locality where the loop is placed. Distances to or from houses, trees, high-tension cables (15 kV) as well as the soil do have an not pre-determinable impact.

4.3.2 Calculation of the coupling loop:

The function of the Magnetic-Loop Antenna over the entire frequency range is heavily dependent on the dimension of the coupling loop !

Long series of measurements with loop - antennas with a circumference ranging from 0.08 to about 0.4 lambda brought no acceptable values to create a general usable formula. The calculation of the coupling must whenever possible be done at the lowest operating frequency of the loop itself.

To simplify the calculation, I then used the ratio of the loop to the coupling-loop. These of course under the conditions of the surroundings. The technical data of the loop therefore are an integral part of the coupling-loop.

Once you have calculated the loop at its lowest frequency, click on '*coupling*'. A new window will be opened. Here the site is then (the environment) select the Loop. One has to select the surrounding (place of operation and its surroundings). By clicking on the button right besides the input button one can change the calculated value. Practical figures are between 3.9 to 5.5:1 . After that the new calculation can be started.

Under '*results*' the degree of coupling loop are then listed. This is around the perimeter of the coupling loop from coaxial cable and the length L_{ka} for the balance on the lowest frequency (see under 6. Balance).

A look to the results will show us the lengths (circumference) of the loop made of coaxial-cable as well as the section of the coupling-loop (L_{ka}) which lies close to the antenna-loop.

For information and for other types of coupling even the resonance resistance of the antenna-loop Loopschleife (with reference to the used frequency) is displayed. This possible loss resistances are taken into account.

5. Why this program?

I looking for a space-saving, yet powerful antenna for my QRP - station (5W), from experiments with mobile antennas discovered the 'magnetic loop - antenna'. This antenna consists of a conductive loop, brought into resonance with a variable capacitor. The circumference of such a loop usually is less than about 0.4λ (λ = wavelength). Remember, at about $\lambda/2$ a loop too becomes self-resonant and therefore no additional component, such as a capacitor will be needed.

5.1 My first Magnetic - Loop - Antenna

First component I was looking for was a reasonable variable-capacitance. In one of my junk-boxes an old one from the glory times of bc-radio rangiung from 2 x 15 to 540 pF I found. By modifying it into a series one it covers the range of 7.5 to 270 pF. Furthermore a small barbecue-motor and a PL-connector were available. At the Internet a magnetic-loop antenna calculating program was found. I quickly started to calculate a antenna working from the 20m to 80m band. With the results, I then created a shopping list:

- 6.5m copper pipe from the roll, matching mounting clips
- a pipe sleeve DN 110 HTM and lid to the variable capacitor - housing
- two cable bushings for damp locations - junction boxes (12mm)
- cable ties

Next I went to the hardware store for buying everything. Before you now take this list and run to the nearest hardware store, please first go on read it on reading!

The copper pipe - roll had a diameter of approximately one meter. Every 5 to 10 cm I now had to bend off the radius of this ring until I reached a diameter of about 2.10 m. The ends I made flat. The measured circumference then resulted in 6.65 m. The variable condenser I mounted between 2 pieces of plastic. Using an isolating coupling it then was fixed to the barbecue motor. It then was placed into the pipe-sleeve. By using a more or less wide flat metallic wire the stator-packet of the capacitor were soldered together with the copper-pipe.

NOTE (attention): be careful with soldering to the capacitor !!

From most literature sources, a loop to coupling-loop ratio of 1:5 is stated. So I placed the PL jack on a loop made of stiff copper wire with 1.30 m circumference and placed it opposite the variable capacitor into the Loop. First tests I made on our balcony, the loop connected to my hf-transceiver via 10 m of coax cable.

The first results were sobering:

- the frequency range didn't fit with what I had calculated and expected. (e.g. the 80 m band was covered only up to 3.65 MHz. 7 m in circumference would have been better)
- bad VSWR on all bands
- the signal strengths compared to the mobile antenna ranged from worse up to just as good
- receiving was possible, even though the antenna was not tuned to the desired frequency (unshielded coupling).

The antenna worked so not yet optimal.

5.2 Optimization of the antenna by series of measurement / Summary

In the coming months, the antenna has been optimized. The Loop itself has hardly been a problem. Of course a low-ohmic and stable construction are prevailed conditions.

The problem is made by the coupling loop, which corresponds especially in the range of frequencies in the range from about 0.25λ up to 0.4λ . The Loop itself behaves as a resonant circuit. Too loose coupling naturally brings losses, excessive coupling damped the loop and also brings back losses. In each case the optimum coupling factor has to be found first. However, this is dependent on the quality factor of the loop, ie of the structure and environment.

Lengthy investigations related to the perimeter of the coupling loop and its various designs were carried out. In addition to the simple wire loops also loops made of coax, were tested. The latter also with at the middle separated shielding, with and without shortening to the inner conductor as well as with a gamma match was tested.

I have found out that the size of the coupling-loop is very much dependent on the diameter respectively the area of the loop itself (not the length of the cable). Furthermore it turned out that the environment of the loop, its quality factor (Q) as well as a not seizable coupling factor, which last but not least is also frequency dependent are mandatory. In practical construction only this coupling factor will make a frequency dependent double-spot tuning possible. The calculation of the coupling with this program must therefore be done always the lowest frequency of the loop. To simplify the calculation, I then resorted again to the calculation of the coupling-loop by a ratio of the two loops depending on the environment taking into account the technical data of the Loop.

As best form of coupling loop proved:

- A loop of coaxial cable with a as thick as possible inner conductor (possibly low capacitance, please do not use RG 58 or similar)
- The full-length shield connected only to one side at the entry point
- The impedance of the cable is not critical (50, 75 or 93 Ohm)
- The entry point must be located spatially at the Loop
- The coupling loop should be placed isolated from the Loop
- A 1:1 - Balun or a common mode choke is advantageous and makes it non-critical to install the coax-cable

Of course, 75 ohm cable or even better 93 ohm cables have the least capacity per meter at the same diameter. Air-insulated 50 ohm cable (Aircom Plus, etc.) but are also quite well. In order to only couple the magnetic field to the loop-antenna itself it is a must that the input-coupling loop must be mounted isolated from the loop. A connection between loop and coupling will result in an asymmetry an "antenna effect".

If detuning the loop, nothing should be heard anymore, even though no strong signals. A field strength meter (detector receiver together with an rod antenna and measuring equipment) placed nearby or directly within the area of the loop should read no indication. In this case one can be sure that only the magnetic component will be radiated. There will be no indication measured until we measure at a distance of approx one wavelength. This one does not generate TVI or BCI in the near field.

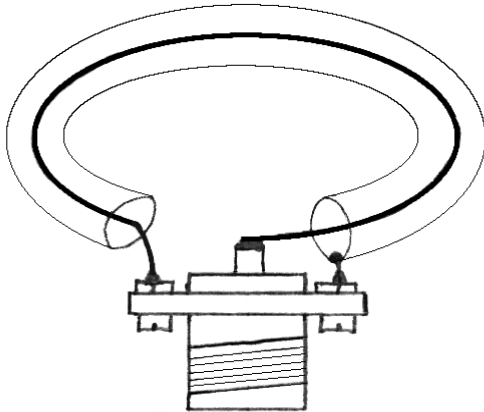


Abb. 2 Circuit a Ankoppel loop of coaxial cable to a PL- socket

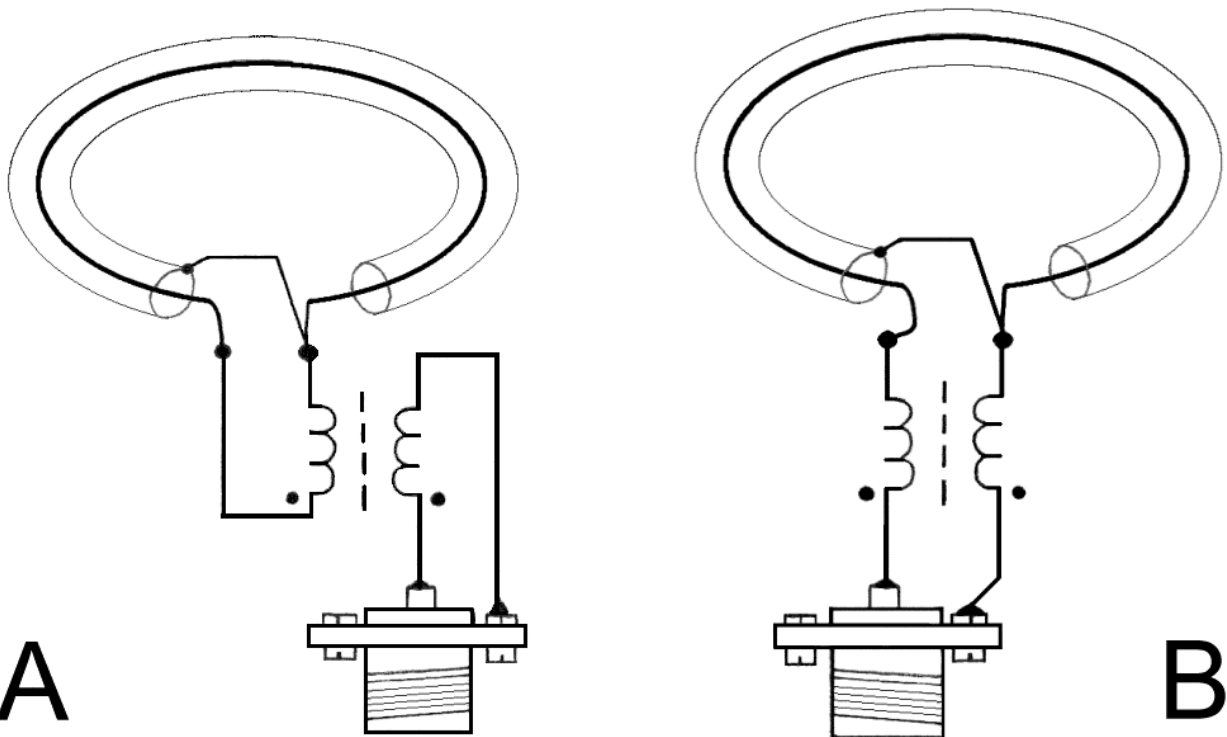


Abb. 3 Circuit a coupling loop of coaxial cable with a 1: 1 Balun: Option A as transformer, variant B as a standing wave barrier. The winding starts are marked with a dot.

Ring Core	2x turns bifilar (1.7 - 30 - 50 MHz)	Wire (Z = 50 Ohm)	max. transmitting power [2] [W]
FT 37 – 43	7	2x 0.5mm CuL about 1.5 drill beats /cm	7
FT50 – 43	6	2x 0.63mm CuL untwisted	17
FT82 – 43	4 - 5	2x 0.8mm CuL untwisted	28
FT114 - 43	6	2x 1mm CuL untwisted	139
FT140 - 43	5	Coaxial Cable	466
FT240 - 43	4	Coaxial Cable	1158

Tab.1 Dimensioning of the 1:1 balun. The B variant can be wrapped at all toroids with coaxial cable.

Circuit changes at high frequencies concerning the antennas shielding may cause a lower efficiency. The reason herefore is an unwanted current at the shielding due to the capacitance to the inner conductor and then going grounded. By the way, a simple wire-loop might be the 2nd. However, at higher frequencies it shows a tendency to capacitive overcouplings to the loop itself. In this case we also will have (unwanted) receptions even though if the antenna is untuned. Under given conditions (closed balcony) the dimensional ratio between the loop and the coupling-loop turned out to be 4.05:1 .

Later I made the same experiments with Loop Antennas having two turns. The results were consistent with the previously determined values. A two-turn loop having the same length of conductor as has a simple loop, working at the highest frequency, will have a smaller area. Consequently it will have a 3 dB efficiency.-loss. With reference to the same frequency the ratio increases (it becomes more worse).By furthermore increasing the number of turns the ration again becomes more worse. All values given in dBd are referenced to a half-wave dipol under free space (ideal) conditions. Other, higher values referenced to a half-wave dipol are values of fantasia.

5.3 Magnetic - Loop Antennas - Calculation Program

The reason I wrote this program was to exclude illogical errors in the measurements. Some formulas I found at the Internert homepage (website) of HB9ABX [1].These formulas I then expanded as well as supplemented by other elektronik formulas. . Gradually I was able to verify the calculations and flipped exclude measurement errors caused by my measurements. In order to not let it be a single use the program is a free usable software.

A commercial use is permitted only with permission of the author.

6. Balancing the coupling loop

The at the lowest frequency calculated values concerning the circumference of the coupling-loop as well as it's lengths (L_{ka}) are defeated by all the surroundings and therefore only approximate values. A tuning (adjustment) of the coupling-loop is always advisable.

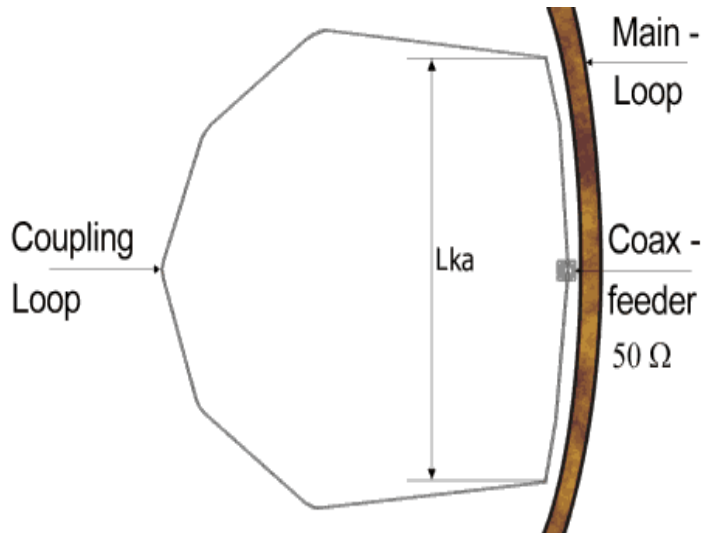


Abb.4 Construction of the coupling loop

The lengths (circumference) of the coupling loop is adjusted to the highest foreseen working frequency. At it's lowest foreseen frequency we have to tune it that way that a (certain) lengths of the coupling-loop comes to lie close to the antenna-loop itself (L_{ka}). In case of extrimity and after tuning the coupling-loop may become the form of a loop-dipol. It should be always possible to have coincidence between the maximum of reception with the standing wave ratio minimum.

In case of that the max. receiving signal does´nt fall together with the vswr-min (in this case we do have 2 minima with the receiving max-value lies in between). However we are at the lowest possible vswr, the circumference of the coupling-loop ist to high.

In case it is the other way around i.e. max. receiving value is at vswr- min., however the vswr isnot acceptable low results in a to small circumference of the loop. (We have to try the tuning at the lowest frequency again as well as checking it again).

At the lowest frequency the coupling loop is bent towards that a certain length (L_{ka}) bears the coaxial cable of the loop at the Loopschleife directly. This results in a standing wave minimum should be better than 1:1.3 (1:1.1 can be often restored) can be adjusted. Is VSWR here but already without L_{ka} so in a circular shape of Ankoppelschleife well, so the Ankoppelschleife is still a little too big. After this adjustment, all frequencies in between have a good fit and thus a good VSWR.

During the calibration work we can fix the coupling loop with a string on the LOOP, than later with UV - resistant cable ties or similar.

7. Practical experience with this type of antenna

To establish a SSB-communication with only 5 W transmit-power is not very easy. You must have a lot of patience and of course a good antenna. As usual I installed my magnetic-loop antenna approx. 1 m outside of my balcony and directed east to west in vertical position. Because of its size (2.10 m dia) it was almost impossible to change the direction. The stations I could reach were of course only within this directions (PA, ON, SP, R). Probably via high-angle radiation also short-skip qso's within short distances into the southern part of Germany where made possible. Dx was almost impossible..

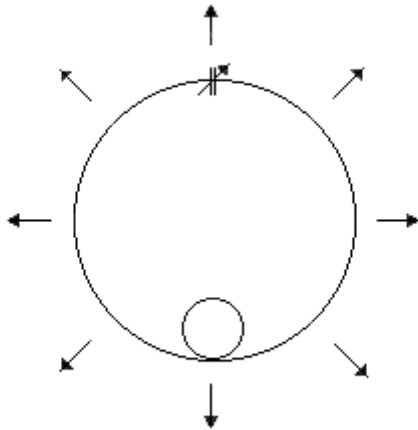


Abb.5 Schematic representation of a magnetic - loop antenna with its idealized radiation directions.

If one considers the radiation directions of this antenna type, it can be seen that a portion of the transmitted energy is radiated into the ground and another part into the sky. Only a small portion is radiated towards the direction to the opposite station. What could be done more than to set up the antenna horizontally. No sooner said than done and the effect was startling. The reports were now increased by about two S - units compared to the mobile antenna. The antenna now became more a low-angle radiating one. Its characteristic became more the one of a beam. European stations were weaker and DX stations have been raised in the signal (20m band). Half of it was on the balcony, ceiling mounted 30cm below balcony (concrete), the other half sticking out of the balcony approx. 15m above the ground. Now also DX was now possible. I could, inter alia, work stations within the 20 m band from the south of Southern America.

Subsequent comparisons of this type of antenna with dipole antennas for the respective bands confirmed the gain made by calculations. On the 20m-band up to 40m band hardly any differences were noted. Only the 80m band was about 2 s-units lower in signal strength. A 2-turn loop, having the same length of conductor (3.25 m radiator and a coil at the feeding point). It is also noteworthy the noise-immunity of the magnetic-loop-antenna. The 15.6 kHz line frequency interferences from a TV set at 2.5m distance received by a wire-antenna could be heard with S 9.. By using my magnetic-loop-antenna almost nothing could be. While transmitting no interference to the TV-set could be detected.

First experiments using this kind of antenna for the 30 m band (in the middle of band) I got no reasonable results. The reason I discovered came from the ringing-wire I used to control the barbecue motor. To just drilling the cable several times and also using a toroid was by far not enough. Even though it all was housed inside the battery-box. The cable of course was arranged downwards and out of the loops plane. However, at the point where the direction of the cable changed into the horizontal another hinged ferrite with several turns became necessary.

In summary it can be said that a Magnetic - Loop antenna with one turn is no auxiliary aerial. A loop with more than one turn only makes sense at the lower HF bands as well as MW and LW where other antennas due to the non-realizable dimensions and at low installation height have a poor efficiency.

8. postscript

Relevant information, suggestions, own examples or measurement results are desired.
(Email: dg0kw@darc.de)

I am not responsible for the content or availability of external internet sites listed here. For the operator is responsible.

Much success when working with the *Magnetic - Loop Antenna - Calculator* wishes you
author K. Warsaw, DG0KW

Literature sources :

[1] Magnetische LOOP Antenne = Mag-Loop, magnetische Antenne

Copyright (c) 2003, 2005, Felix Meyer, HB9ABX, Formeln, welche dem Berechnungs-
Programm zugrunde liegen <http://home.datacomm.ch/hb9abx/loop1.htm>

[2] Belastbarkeit von Ringkernen, Peter , DL2FI, QRP-REPORT, 6.Jg, Heft 3-2002, S. 21

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