Magnetic Loop Antenna with Additional Loop for Frequency Extension

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This report describes the frequency extension of a magnetic loop antenna by a second conductor ring (loop). The described realization is based on an AMA82 antenna, but the concept can also be applied to any other magnetic loop antenna.

Initial situation: A magnetic loop antenna, type AMA82 of WIMO /1/ was installed on a balcony of my apartment on the second floor. The antenna can be tuned over a wide frequency range, with 2 octaves from 3.5 MHz to 14 MHz, which is associated with problematic impedance match at the upper end of the frequency range; in a previous post, the impedance match of the antenna was investigated accordingly, and a matching circuit was designed /2/. But actually, an even wider frequency range would be desirable, especially with regard to the DX possibilities of higher bands.

A simple plan: The idea was to simply introduce a second, smaller loop into the existing, larger loop, with a fixed capacitor to tune it to the lower end of the 21 MHz band. In Fig.1 you can already see the realization: A 15-mm dia. copper tube was bent into a ring with a diameter of 95 cm and the open ends were connected with a fixed capacitor of about 20 pF placed in a weather-proof housing. This ring sits on the large ring of the AMA82 which is made of 35-mm dia. aluminum tube and is clamped, so that the two rings are tightly connected at the bottom but free at the top, in the range of high electric field strengths. Below you can also see the much smaller feed loop, which is connected to the transceiver and can effectively excite both loops on their resonance frequencies.

First, the simulation: However, this extension was not realized without prior simulation with EZNEC; the simulation model can be seen in Figure 2. There was a big surprise, as the second loop works other than expected: Due to the high Q-factors of the two resonance loops in the range of a few hundred, there should be practically no interaction between the resonators at a frequency separation of several MHz. However, the simulation shows that the two loops are closely coupled with each other via their magnetic fields so that if one loop is excited at its resonance frequency and carries a strong current, this current induces a considerable current in the respective other loop, even though this loop in this case is far from resonance. So: If the large loop is tuned to 14 MHz and is fed with 14 MHz power via the coupling loop, a large current flows in it, but also a considerable current in the smaller loop, which is tuned to 21 MHz. And conversely, a large current flows in the smaller loop when the antenna is fed with 21 MHz but also a considerable current in the large loop, which is tuned to, e.g., 3.5 MHz. In Figure 3, this can be observed in the current distribution plotted above the wires. The ratio of the large to the small current amplitude is about 1:5 to 1:6. However, one must also observe the phase relation of the two currents: The magnetic coupling of the two loops forces the (smaller) current in the (smaller) loop, which is tuned to a higher resonance frequency, to flow in the same phase when the antenna is fed at 14 MHz. Thus, this induced current supports the radiation of the large loop which is accompanied by a small increase in the radiation resistance and thus also of the antenna gain by 0.3 dB. In contrast, the (smaller) current in the large loop, which is tuned to a lower frequency, flows in 180° anti-phase to the larger current in the small loop, when this is excited at 21 MHz. Since both loops have about the same radiation pattern, the anti-phase radiation of the large loop in this case reduces the far-field amplitude and thus also the antenna gain. Note that the large loop has a radiation resistance in the ratio of 10:1 in relation to the small loop because of the ratio of diameters. Therefore, a ratio of the loop currents of (-1):6 nevertheless results in a far-field ratio of about (-1):2, so the far-field amplitude is halved by the anti-phase field. The consequent degradation of the antenna gain is about 6 dB as long as the large loop is tuned at 3.5 MHz up to 10 MHz. Tuning the large loop to over 10 MHz, the unwanted anti-phase current increases significantly to a ratio (-2):7, so that the loss increases to 18 dB when the large loop is tuned to 14 MHz.

The good news: But this is only one consequence of the strong coupling of the two loops: Unexpected and very pleasant is that the small loop can be tuned by tuning the large loop. E.g., tuning the large loop from 3.5 MHz to 10 MHz, the 15-m band resonant frequency is tuned from 21 MHz to 21.3 MHz. This means, despite the fixed capacitor in the small loop, the 15-meter band can also be tuned via the AMA Control Unit.

As a further consequence, the close coupling of the loops supports the impedance transformation of the small feed loop and thus positively influences the impedance match of the antenna: The original reflection factor curves for the four bands from 3.5 MHz to 14 MHz are shown in Figure 4. With the additional loop, all curves shift slightly, see Figure 5, but the higher frequency bands shift most. In the 20-meter band, where the VSWR was above 2.6 without a matching circuit, it now falls to 1.7. The resonance curve of the 15-meter band is additionally entered in the figure showing almost perfect match; the bandwidth is 60 kHz @ VSWR=2.6. This means that the VSWR is below 1.7 across all frequency bands in this case. This is certainly an acceptable impedance match, but it is even better with the matching circuit from /1/. The corresponding reflection factor curves are shown in Figure 6; the VSWR over all bands from 80 m to 15 m is below 1.36.

The second loop as a parasitic element: If a frequency extension is not desired at all, the second loop can also be operated as a purely parasitic element, which in this case is only to improve the impedance match of the antenna in the higher frequency bands. According to the EZNEC simulation, the fixed capacitor would have to be dimensioned at about 35 pF to compensate the poor match at 14 MHz and 10 MHz; the resonance frequency of the second loop would then be about 16.6 MHz. In this application, the fixed capacitor would not have to have a particularly high dielectric strength, while in my application as a frequency extension to the 15-meter band, an air-plate capacitor with 2 mm plate spacing only reaches up to 50 W input power. Figure 7 shows the open plastic box with the self-constructed capacitor with plates made of 1-mm copper sheet and an adjustable copper disc for fine tuning. First tests with RF power in the 15-meter band brought violent discharges with traces of fire and soot in the housing, until the dielectric strength could be permanently increased by pasting the plate edges with some UHU-Plus epoxy.

Operating experience: In the operation of the antenna on the 15-meter band, it was first noticed that the interference noise (local QRN) of the house and the surrounding area is several S-units lower than on the 20-meter band – this is certainly partly due to the reduced antenna gain because of the ant-phase current. However, the antenna gain is sufficient to run QSOs with medium to high signal strength stations, and, especially in contests, also DX QSOs. It is then also clear that the antenna should be completely sufficient for digital modes, such as FT8 etc.

References:

/1/ https://www.wimo.com/de/ama-82

/2/ Klaus Solbach, "Magnetic Loop Antenna: Improving the Impedance Match", August 2022

Fig.1 AMA82 - Antenna with second loop on our balcony.

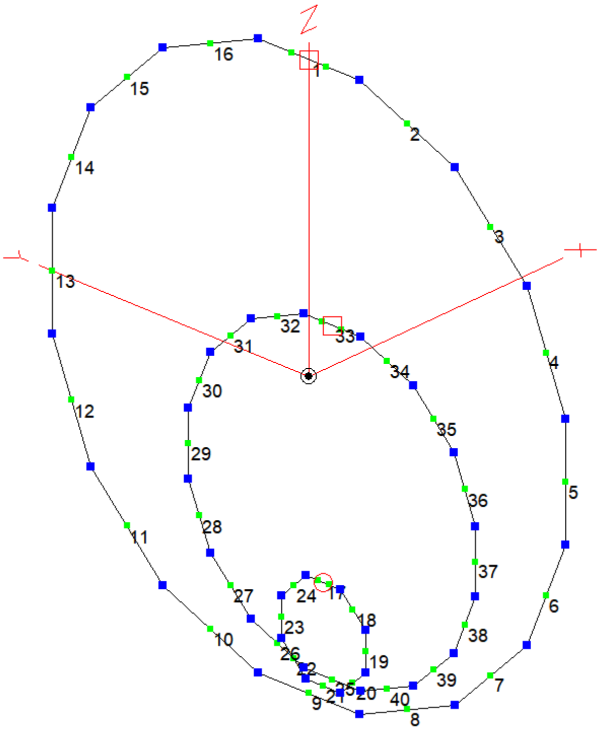

Fig. 2 EZNEC simulation model of the AMA82 with second loop (wires 25 to 40) and feed loop (wires 17 to 24).

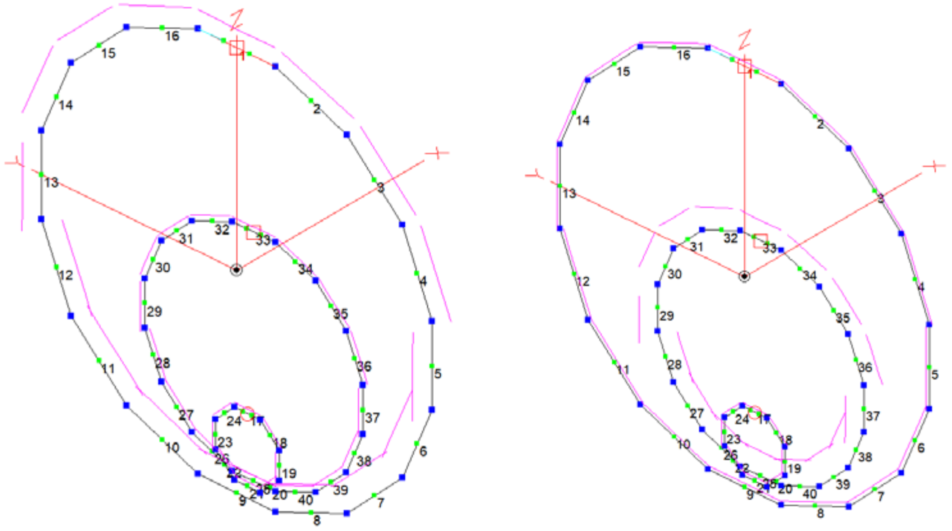

Fig. 3 Current distribution on the antenna wires when the antenna is excited with 14 MHz (left) and with 21 MHz (right).

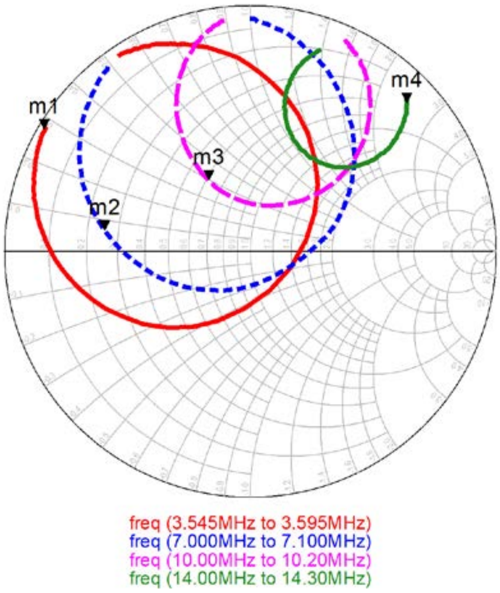

Fig. 4 Measured reflection factors from 3.5 MHz to 14 MHz without second loop.

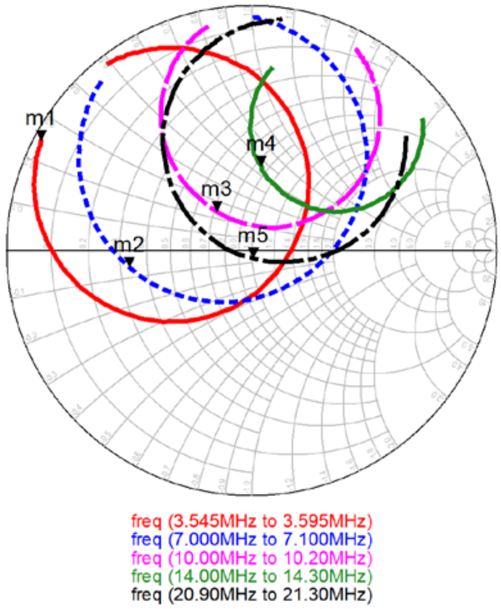

Fig. 5 Measured reflection factors from 3.5 MHz to 21 MHz with second loop installed.

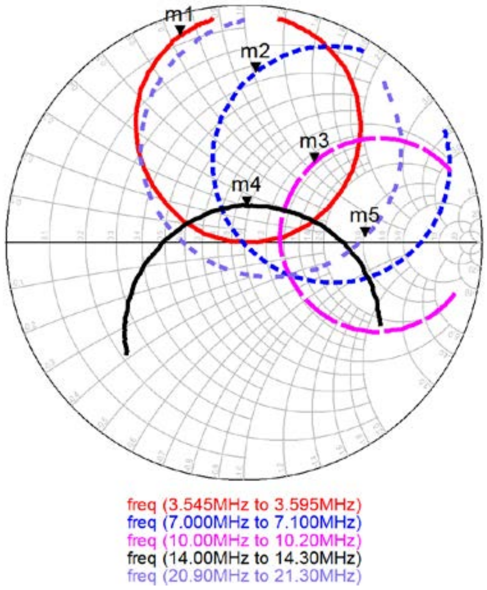

Fig. 6 Measured reflection factors with second loop installed and with matching circuit.

Fig. 7 The fixed capacitor between the ends of the small loop in the weatherproof housing on the mast of the AMA82.