Something about Antenna Tuning Units

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What an ATU does?

You should not think that an Antenna Tuning Unit (ATU) is a magic thing to do any antenna work well with your transceiver. At installation between the transmitter and feeder the ATU only does matching of output impedance of your transmitter with input impedance of your antenna - feeder system. It means that ATU allows to the transmitter with output of 50 Ohm to work normally with antenna plus feeder having any input impedance. But probably SWR would be enough high in the feeder. If the ATU is installed between antenna and feeder it does low SWR in feeder and provides good operation for the transmitter. But probably the antenna would work not in good way.

So, an ATU provides safe operation for transmitters end stage, if the ATU is between the transmitter and the feeder, additionally an ATU does low SWR in feeder, if the ATU is installed between antenna and feeder.

As usual modern transceivers and military equipment have inner ATU that does matching end stage with feeder or antenna. Below we take close look to ATU design.

ATU Design

Fig. 1 shows schematic of a “classical” ATU. Such ATU has:

- a Matching Unit, that provides the matching of end stage of the transmitter with antenna - feeder system. Matching Unit is the “heart” of any ATU;
- A SWR mater or HF-bridge, that shows how the matching is done;

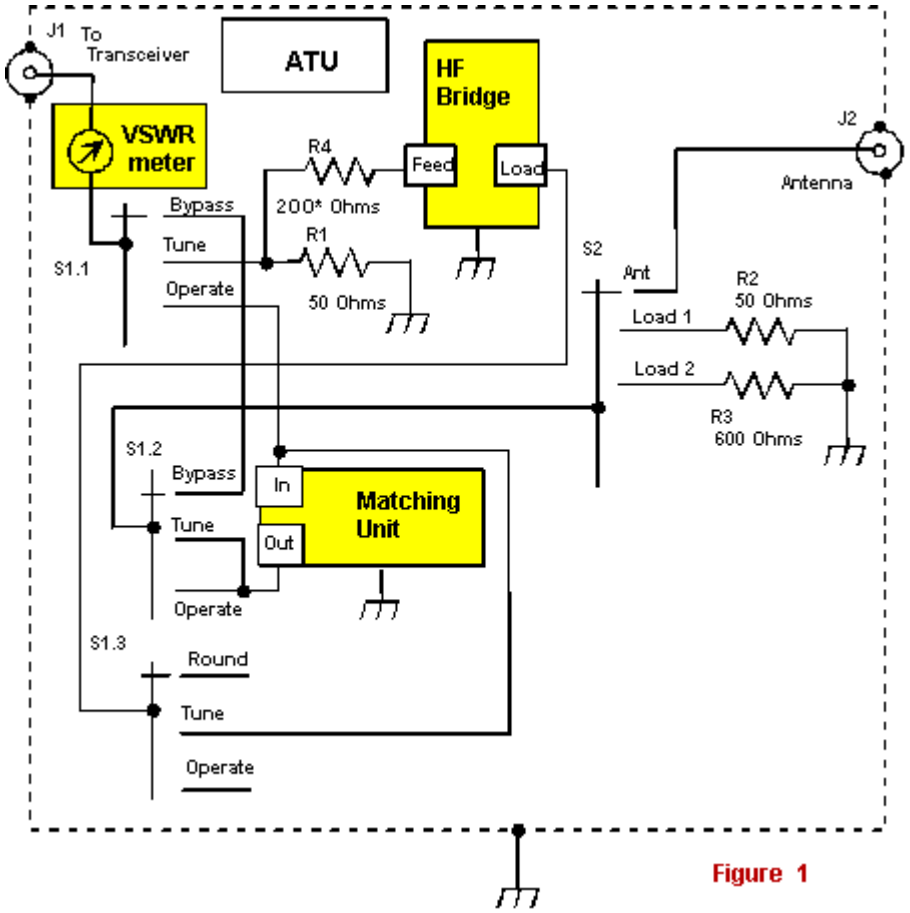

Figure 1

- Dummy loads R1, R2 and R3, that help us to monitor how Matching Unit and SWR – meter (HF-bridge) do work:
- S1 and S2 for proper connection of the above mentioned parts;
- J1 and J2 for transmitter and antenna connection.

So, how the ATU does work?

S1 at "Bypass" position does connection of the transmitter to S2. S2 does connection or to antenna, or to Dummy Loads R2 (50 Ohms) or R3 (600 Ohms). So, at good 50-Ohms antenna the transmitter works straight on the antenna, also is possibility to load the transmitter on 50-Ohms Dummy Load for a tuning of the transmitter or checking of the SWR- meter.

S1 at "Tune" position does connection of the transmitter through inner HF-bridge and Matching Unit to S2. So, it is possible to tune the Matching Unit or on to real antenna (S2 in position Ant) or check how the Matching Unit can tune to 50-Ohms (S2 in position Load 1) or 600-Ohms (S2 in position Load 2) load. When you have your antenna tuned, switch S1 in position "Operate" and just work in the ether.

You can see, it is possible to use or SWR- meter or HF-bridge for tuning the MU on to real load.

As it is visible from this scheme the degree of the matching of the transmitter with used antenna depends only on used Matching Unit. Let's see what our Matching Unit can contain.

Classical Matching Unit

One of most effective Matching Units is shown on **Fig. 2**. This scheme was widely used by the radio amateurs from early 30s till recently days. As it is visible from **Fig. 2**, the end stage of the transmitter is connected through coupling coil L1 and coupling capacitor C1. L2 and C2 is tuned to resonance to input signal. C3 does coupling with the load (antenna).

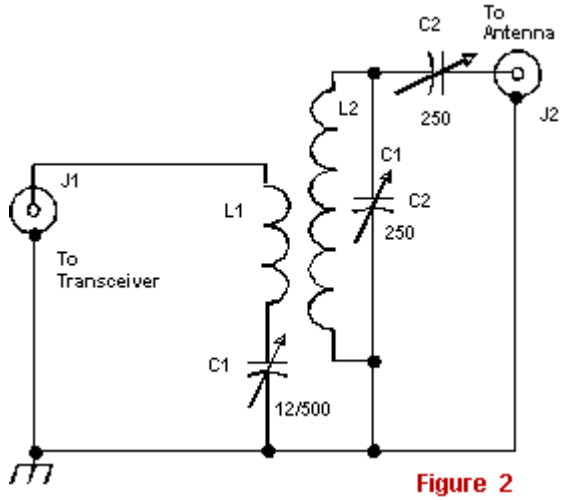

Figure 2

As usual, L1 has from ¼ to 1/6 from amount of turns of L2. L1 is winded in lower part of L2. L1 should be unbound from L2 by any qualitative isolation. In some designs of the MU, L1 is isolated by means of air. The transmitter is coupled to the antenna only by magnetic field, so the end stage of the transmitter is protected from a lightning. Resonance circuit kills harmonics. The Classical Matching Unit does well match a load from 10 to 1000 Ohms with end stage of transmitter in 50 or 75-Ohm impedance.

C1 should have maximum of capacity up to 1500-pF at operation through 1,8- 28 MHz, and 500-pF would be enough for operation through 3.5- 28 MHz. If L1 has optimal number of turns the C1 is not necessary at all. C2 and C3 should have the greatest possible clearance between their plates.

At constant parameters of L1 and L2 the Classical Matching Unit works with high efficiency only in two multiple amateur HF - ranges, for example, 1,8 and 3,5 MHz, 7 and 14 MHz and so on. At others ranges efficiency is dropped. Old Classical Matching Unit had plug-in coils for all amateur range for keeping the efficiency at high level. L2 should be placed as far as possible from metal walls of the cabinet of the ATU.

To tune the MU is very simple. At first, C1 has the maximum capacity, C2 and C3 have minimum capacity. Then, with help of C2 do tune resonance circuit L2C2 in the resonance to working frequency, then C3 does optima matching with the antenna. After that once more time do tuning C2 and C1. It is necessary to say, that after final tuning of the MU C3 has to have the greatest capacity as it is possible.

Advantages of the MU are following. It does not require too careful manufacture of L1 and L2. The system ensures high efficiency, up to 80 percents. Tuning is done with two capacitors C2 and C3. The lacks are that for high efficiency in the matching unit it is necessary to use one spool to two multiple ranges, and one variable capacitor insulated from case of an ATU.

Classical Matching Unit with a symmetrical output

Recently symmetrical antennas with a symmetrical feeder are applied seldom, but some decades ago it was a usual matter. Classical Matching Unit with symmetrical output is shown on **Fig. 3**. In scheme shown in **Fig. 3** a RF- voltage for antenna - feeder system is removed symmetrically from both ends of L2, and it is only difference from the scheme shown in **Fig. 2**. In practical design L1 should be disposed symmetrically concerning resonance spool L2. Twins capacitors C2.1 and C2.2 should have one axe. It is as well as to C3.1 and C3.2.

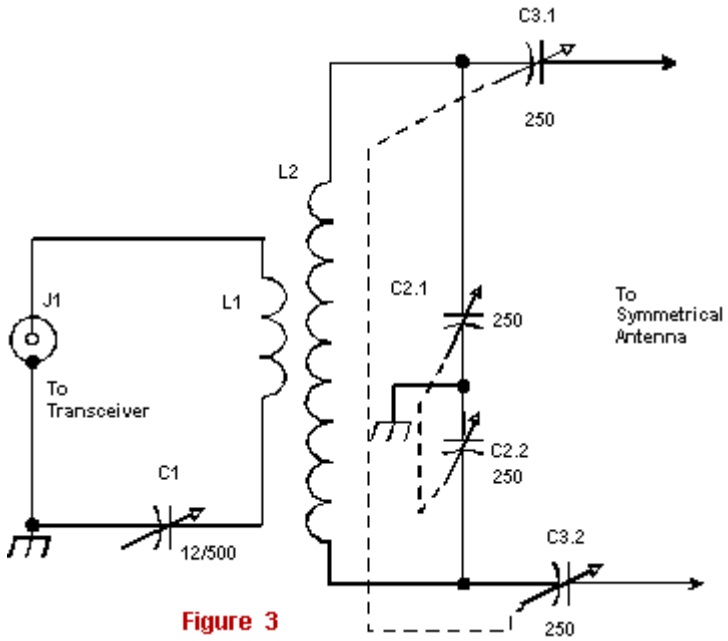

Figure 3

Classical Matching Unit with taps

You can see that C3 is isolated from metal cabinet of the ATU. It is not convenient for practical design of an ATU, so amateurs often use Classical Matching Unit with taps.

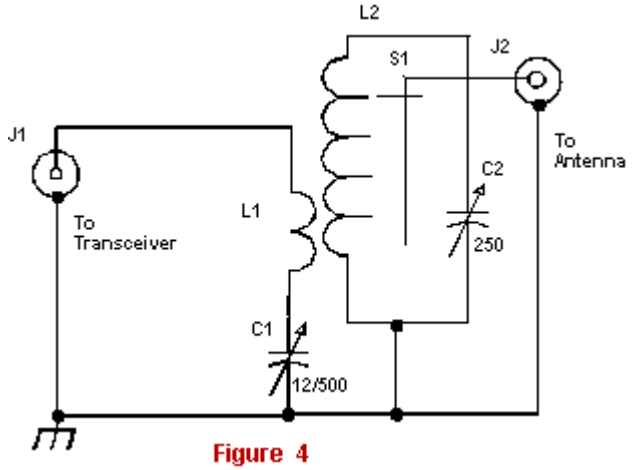

Figure 4

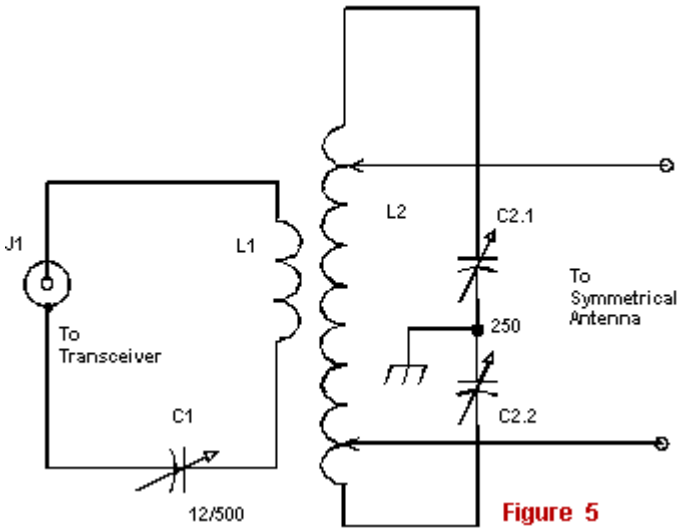

Figure 5

Fig. 4 shows such MU with asymmetrical output, **Fig. 5** shows Classical Matching Unit with taps with symmetrical output. These schemes (**Fig. 4 and 5**) cannot give such careful matching, as shown in **Fig. 2** or **Fig. 3** have provided**.** But in case if it is need to minimize dimensions of an ATU the schemes can be used.

Multi-range Matching Unit with taps

So, if you want to build an ATU having minimum sizes and parts try the schematic shown in **Fig. 6**. However, the Matching Unit has not high efficiency at upper amateur ranges because of lowering of the Q-factor of L2 and because of not optimal selection of taps from L2. But usage of such simplified multi-range Matching Unit at amateur HF - ranges 1,8-10-MHz is quite acceptable.

T - Matching Unit

Classical Matching Unit is very effective in the work. However, among radio amateurs and military T-Matching Unit has more popularity then one shown in **Fig. 2**. It takes place because T- Matching Unit have high efficiency at very wide frequency ranges and T-Matching Unit allows to do easy automatic tuning (that very likely to the military!). Also, T- Matching Unit works very well with for asymmetrical coaxial cables feeding modern antennas. **Fig. 7** shows schematic of T- Matching Unit. The MU has rather good parameters. It is possible to do matching a 50–Ohms transmitter to 10- 1000-Ohms antenna. It is possible overlap all HF- amateur bands from 3,5 up to 30 MHz using only one variable inductor at 0.5-30-μH and two variable capacitor at 10- 250-pF. The MU does matching at 1.8-MHz if to bridge C1 and C2 to connect fixed capacitors at 200-pF.

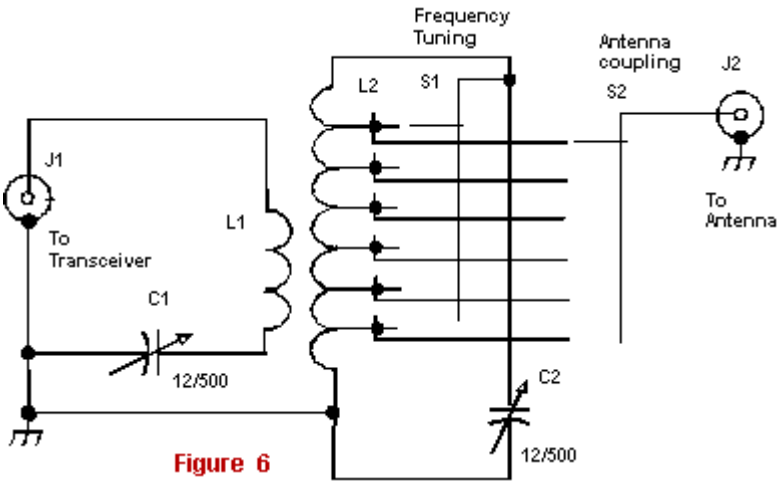

Figure 6

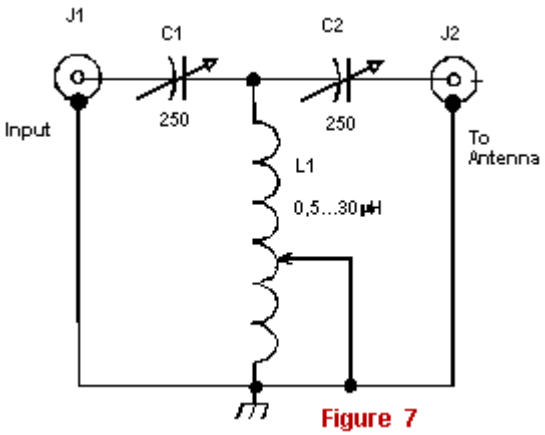

Figure 7

The “cold” end of L1 should be grounded or isolated carefully from the metal case of ATU. Otherwise you probably will have strong arc between the ungrounded end of L1 and a wall of the ATU, as it is shown in **Fig. 8**. C1 and C1 should be very qualitative with aerial or vacuum dielectric. The clearance between plates of capacitors should be not less than 2-mm/ to 200-W bypass power. Stray capacitance of C1 and C2 to the metal case of ATU should be no more than 25-pF, otherwise the efficiency at 24-28-MHz drop.

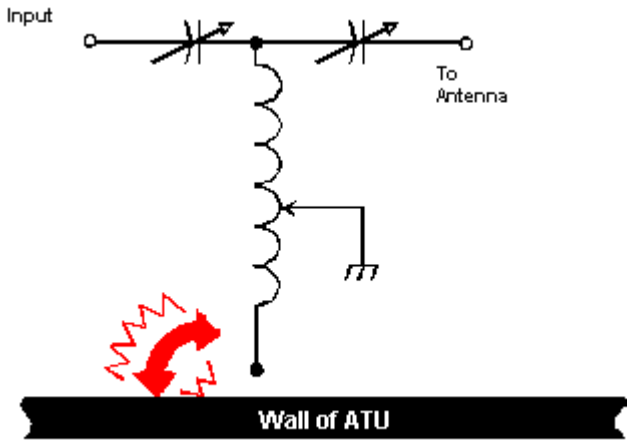

Figure 8

Figure 8 Arcing inductor

If you want to connect symmetrical antennas feeding through symmetrical ladder lines to the T- Matching Unit, use symmetrical transformer 1:4 or 1:6. BTW, many of symmetrical antennas, feeding through ladder lines have large reactive component, which bad to transformation by simple transformers 1:4 or 1:6. The T - Matching Unit suppress harmonics up to 10-15 dB.

T - Matching Unit with a “digital” inductor

L1 has to have slide contact to operate the MU in proper way. Sometimes, even extra half of a turn influences to the matching. It restricts usage of an inductor with taps, or demands personal selection taps for real antenna, that certainly, restricts possibilities “tap” MU. Simple decision on this problem by W3TS made, he offered a “digital” inductor that **Fig. 9** shows. Really, it is possible with the help of several switches very fine to tune needed inductance. Electronic relays with special chips allow realize automatic ATU. Military also use the method at their automatic ATU.

T - Matching Unit with mirror parts

For practical design of any ATU it is not conveniently to have two capacitors insulated from the ground. AEA corporation (USA) does the MU as **Fig. 10** shows. You can see that they changed C to L. Really, schemes of MU figured in **Fig. 7** and **Fig. 10** are equivalent.

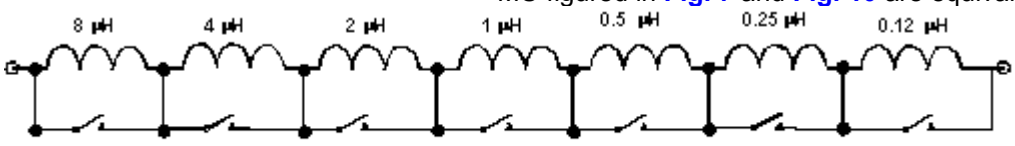

Figure 9

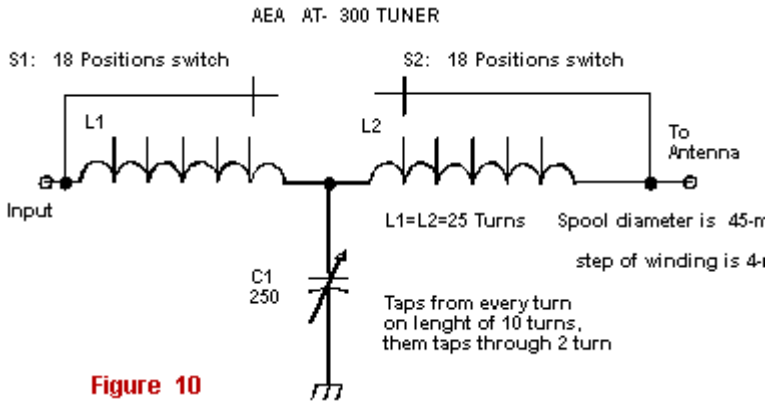

Figure 10

But scheme in **Fig. 10** has advantages. At first, it is much easier to use only one grounded high-quality capacitor instead of two ones but insulated from metal cabinet. Secondly, it is wise to substitute expensive inductor with slide control to two cheapie spools with taps.

The MU made by me at home conditions worked well on all amateur ranges from 1,8 up to 30 MHz and did matching to 50-Ohms transmitter to antenna with resistance from 15 up to 500-Ohms.

The inductors were made as **Fig. 11** shows. Form of inductors is made of PC – board with slots for turns. On the plate switch for taps is installed. The plate is disposed not in center of the inductor but little sideways as **Fig. 12** shows.

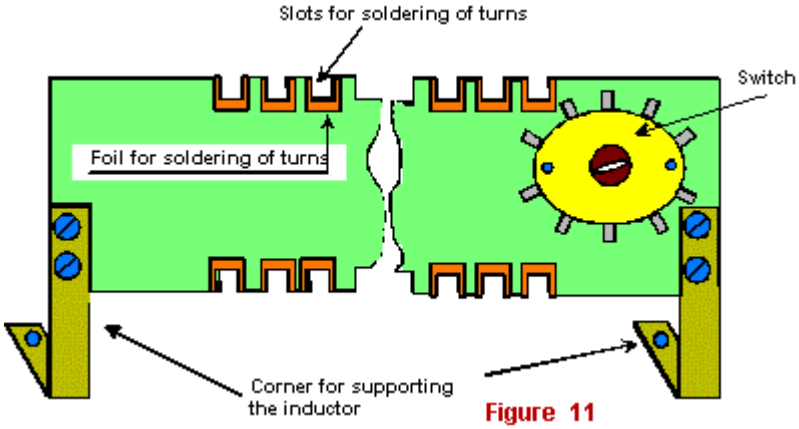

Figure 11

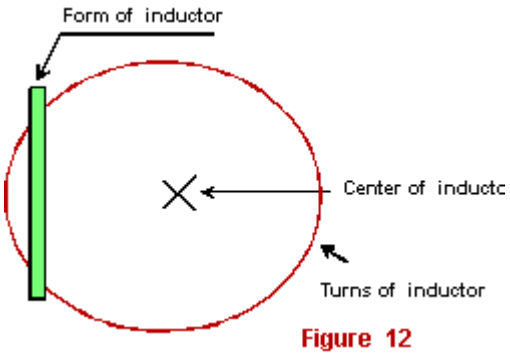

Figure 12

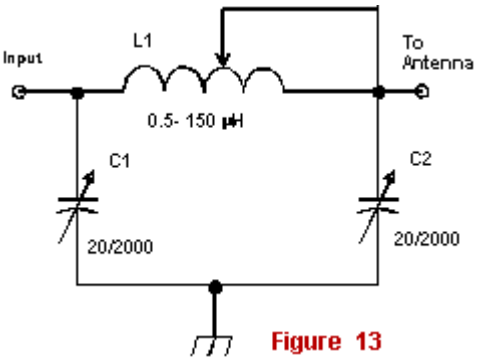

Figure 13

Pi- Matching Unit

Pi - MU is used in radio amateur practice for a long time. It is possible to find Pi - MU and disputes on this subject at radio amateur journals issued on 20s of the 20 century till our time in the Internet. **Fig. 13** shows Pi– MU. As usual Pi – MU is used at inner MU at tube and transistor PA or straight at antenna clips..

Pi – MU seldom is used at separate ATU. For matching in a wide frequency ranges loads with resistance 10-1000- Ohms it need to change C and L at Pi – MU too greatly. So, it is impossible to do universal Pi – MU.

It is desirable to use slider inductor because. In case if an inductor with fixed taps is used you can carefully to select the tap for real antenna.

L- Matching Unit

Fig. 14 shows L- MU. This one is a simplified version of Pi – MU. ATU, keeping L- MU often is used for operation with simple tube and transistor transceivers and for matching simple multi- range antennas, which do not contain large reactive component.

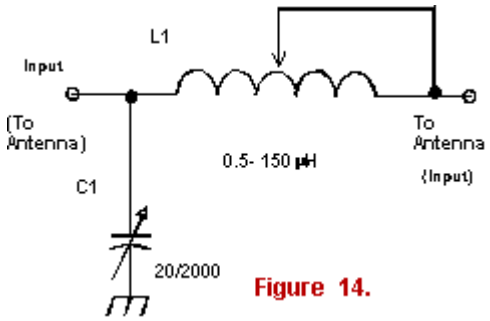

Figure 14.

Parts for the ATU

The data of spools for the MU exhibited on **Fig. 2** are shown in **Tab. 1**, for the MU exhibited on **Fig. 3** are shown in **Tab. 2**.

Table 1 Data for MU exhibited on Fig. 2

Frequency band, MHz	1,9	3,5-3,8	7	10	18	14	21	24	27-30
Diameter of spool, mm	50	30	25	25	25	25	25	25	25
Length of winding, mm	50	30	40	40	40	40	30	30	30
Number of turns	100	30	20	15	10	11,5	8,5	7,5	6,5

Table 2 Data for MU exhibited on **Fig. 3**

Frequency band, MHz	1,9	3,5-3,8	7	10	14	18	21	24	27-30
Diameter of spool, mm	50	40	25	25	25	25	25	25	25
Length of winding, mm	60	40	40	50	40	40	40	40	35
Number of turns, n	130	35	28	20	15	11,5	11	9,5	8,5

Tab. 3 Data for digital inductor shown in **Fig. 9**

Inductance, µH	8	4	2	1	0,5	0,25	0,12
Diameter of spool, mm	30	20	20	20	25	10	10
Length of winding, mm	30	20	25	20	20	10	10
Number of turns, mm	20	18	12	8,5	5	6	4

It is possible to use for T –MU any variometer, which is possible to get. Variometer has to have maximum inductance not less than 30-µH and minimum close to zero. If the maximum of the inductance of the variometer is less, for expansion of frequency range of the ATU to include in serial with the variometer a fixed inductor. If the minimum inductance of the variometer does not reach zero, it is essentially cut off the upper range of operation of the ATU.

The design data for spools for digital inductor shown on **Fig. 9** are shown in **Tab. 3**. Significant RF-currents flow through parts of MU - capacitors, inductors, and switches. So all of the parts should be qualitative.

73! I.G.