SAMS - Symmetric Antenna Matching System

or

A somewhat different Antenna Matching Unit

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The present Situation

Because of their advantages, symmetrical antennas are popular and wide spread amongst commercial as well as amateur services. Especially the latter use these antennas extensively, not only in their own frequency dimension but over whole frequency bands and even ranges.

Physical factors govern antenna impedance, being dependant on the construction situation and its working frequency. The impedance range can vary between a few ohms right up to kilo-ohms, whereby impedance is of a complex nature and very often influenced by high reactive blind components.

The results are high SWR on the feeder, which augments signal-loss and can lead to flashovers in high-power ranges. To minimize loss, feeders run with high SWR should be constructed as open feeders (400 ….600 Ohm). But laying this kind of lines in buildings can cause problems, not least because of extensive electrical fields.

Today's transceivers and linear amplifiers are intended for connection using 50 ohm coaxial cable and there is a real need for an antenna matching unit capable of the following:

- Suitable for feeding-in in standard 50 ohm technology
- Conceived for connection of symmetrical feedlines or -cables / antennas
- High adaptability and able to transform impedances as well as compensate reactances.

It is obvious, regarding the above facts, that solutions involving matching units should not be placed in close proximity to the radio station, especially in high-powered areas. This is valid for so-called automatic tuners too, which can be run remote but are generally not for feeding symmetric antennas or lines or conceived for high power. Alternative solutions need to be found.

The Idea

The described problem is about as old as radio in general and I could not find any really convincing solution within amateur radio itself. And because I understand our hobby to be a medium in which we innovate, develop and realise ideas, the project towards antenna-matching was soon born.

I thought that, in the age of computers and fast band and frequency change, an antenna-matching system should do a lot more than those commercially constructed and on the market at the time. I also could not accept a surplus solution, as I wasn't running a museum station, but wanted my outfit to be using the

An antenna's purpose is to draw energy from an electromagnetic field, or to convert the energy sent from a HF-Generator (Transmitter) into electromagnetic energy.

The simplest and most-used type of antenna is the half-wave dipole. This has, as the name suggests, an physical lenght of nearly a half the wavelength of the dimension-frequency. The dipole is then said to be in resonance.

Resonance is characterized by the absence of imaginary parts in the antenna's impedance. That means that the energy flowing to the antenna meets just a non reactive resistance, resulting of radiating resistance and loss resistances which all are pure ohmic.

Resonance is only acquired at the dimension frequency or its harmonics. In any other case the real resistance is accompanied by reactance or blind resistance. These reactive parts of the antenna's impedance (capacitances or inductances) are regarded to be in series to the radiation and loss resistances of the antenna.

An antenna can also be regarded as a resonant circuit, where, in resonance the reactances from L and C compensate each other and are virtually undetectable.

As in other resonant ciruits, an antenna depends on high quality to achieve high efficiency. Unfortunately there is another rule: High quality also means a narrow range of resonance and this is not what the operator likes, although it stands for a high efficient system.

Reactive loading is, however, to be avoided because this only raises the load on the system without achieving better performance.

The principle of complex conjugated matching CCM allows to compensate every value of inductive reactance by a capacitive reactance or vice-versa.

What is left is just the ohmic component of the impedance, which can then be adjusted through the most high-end technology available.

I now had to specify the general requirements of a new matching-system and this was the result:

- Antenna-matching system for symmetric (and later asymmetric) antennas
- Frequency range* 1.8 to 18 (30) MHz (impedance dependent)
- Coaxial 50 Ohm feed.
- Constant load* 2.5 KW
- Matching range** from less than 10 Ohm to above 1000 Ohm (frequency dependent)
- Reactance compensation range** up to and above +/- 1000 Ohm (frequency dependent)
- Remote mounting of adjusting unit, weatherproof build.
- Control-panel in shack
- Manual or automatic operation
- Automatic matching in case of reception too***
- Ease of construction, using mainly standard components.

  * Frequency range and maximum power depend on load-impedance.

  ** Matching and reactance compensation ranges are frequency dependent.

  *** Parallel running with ICOM transceivers with CI-V interface. Other transceivers can be coupled through a PC data converter such as the logbook software Swisslog.

Attention: All values given are for orientation only. They may be negatively influenced by adverse conditions. It is advisable to consider matching problems during the planning phase or, at latest, before using the equipment.

The Solution

As often is the case, the solution was found after consideration of all possible parameters. The object of the equipment, matching and providing symmetry, resulted in the following problems, which will be defined.

Symmetrising

In my view, most commercially available matching systems make the mistake of fitting the output of the instrument with a ring-core balun (generally 1:4), which is intended to ensure symmetry of signal. In this case it is disregarded that all ring-core materials have a finite saturation limit and are sensitive to reactive loading (with blind resistances). Usually under-dimensioned for real loads, they quickly saturate with reactive current, leading to overload, overheating and intermodulation and consequent influencing of the transmission. A useless solution, as far as I'm concerned.

Another method of symmetrising involves setting up an inductive signal-coupling into a parallel resonance circuit, onto which the symmetrical feeder line is joined. This form of coupler was (and partically still is) very popular and was propagated by its German manufacturer Annecke, unfortunately now deceased. The disadvantage of this solution is that the Q-factor of the parallel resonance circuit varies with frequency and can go so high that the voltage on the components can provide dangerous values. Flashovers can result, with all their horrible consequences. Therefore I was compelled to disregard this solution as well, because I considered its use is too unsafe in non continuous controlled operation especially with high power.

The only remaining, practical solution was to achieve symmetry using a 1:1 balun transformer, inserted in the 50 Ohm section of the matching system (Fig.1). The balun is situated at the input and is not loaded with reactive current, which has already been compensated for in the matching network.

Matching-network and Reactance-compensation

As already stated, we radio amateurs don't usually run our antennas in a state of resonance. The antenna impedance is generally not only real, but polluted by capacitive or inductive blind resistances. Added to this, the feeder cable impedance will hardly coincide with the antenna impedance. The feed cable works, then, as an impedance transformer and presents an often nearly incalculable load impedance at the point of feed.

So it's clear that a matching network needs to be able to accommodate a wide matching area as well as a wide range of reactance compensation. It's obvious that all this needs to be combined and bring a maximum of degree of efficiency - anyhow, every watt of heat needs to be safely drained.

The best circuit appeared to be a T-network in high-pass configuration (see Fig. 1). This circuit is a good compromise in filling all requirements. It produces optimal effectivity, is easy to set up repeatedly and has sufficient integrity for remote and therefore non direct operator-controlled use.

The knowledgeable observer will notice that the matching system only has one inductivity, and could ask if this meets the requirements of a symmetrical unit. The answer is a convinced 'yes'. The symmetrising occurs at network input and the antenna represents a complex impedance which is being mirrored in the matching system (complexly conjugated). It doesn't matter whether the inductivity is in only one, or divided between both the two poles .

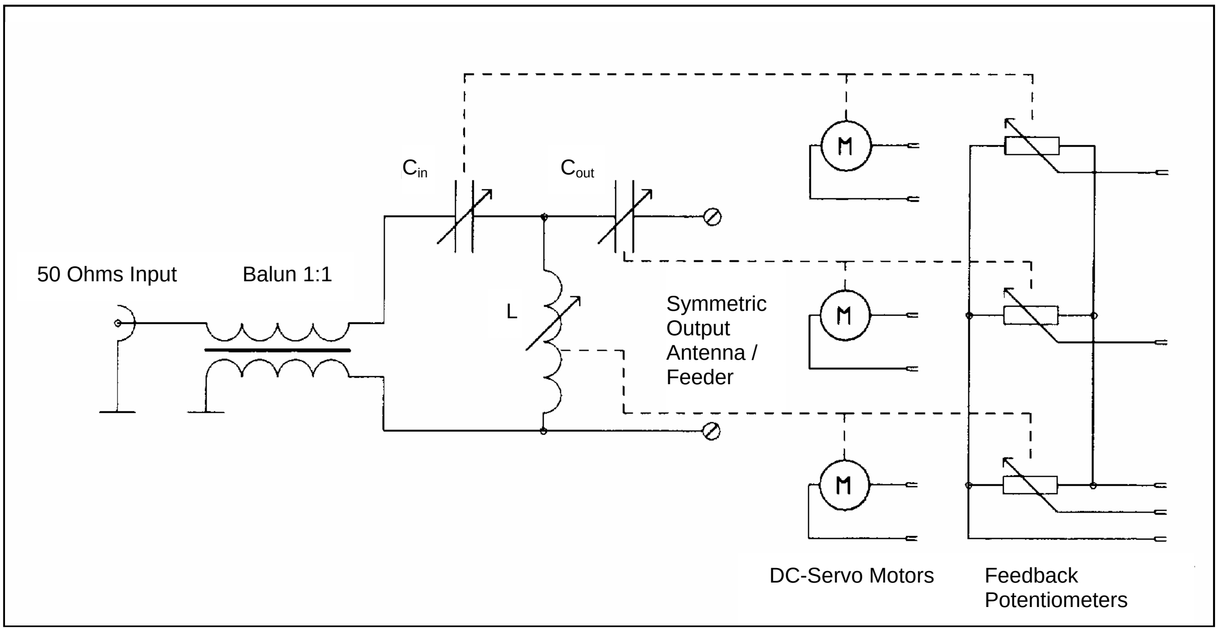

Fig 1: Matching network principally circuit diagram

Instrument Control

A remote matching unit has the great advantage working on a coaxial cable exactly where it should, i.e. either direct on the antenna or at the end of a low-loss feeder line. But, as things are in life, even this solution has its price. It means that this unit needs to be remote-controlled and some effort has to go into this.

This effort is called electronics, complemented by servos and positioning sensors for the network's components. Although it's a ground-rule of mine to avoid electronic circuits and especially processors in the remote unit, so here are only the servos of the variable capacitors and inductors and the feed-back-potentiometers. They all are wired with a shielded 15 pole cable which runs parallel to the coax, back to the shack.

In the shack, we have the control-panel, which is configured for both manual and automatic use. This control-panel is in a metal housing containing all the electronics and the power supply unit of 115 or 230VAC.

All switches etc. are accessible at the front panel. Fig 3 shows:

- A digital readout for each component (present-value) and 3 keys (left, right and fast), altogether 3 sets for C_{in}, L, and C_{out}
- A set of keys for mode selection manual / automatic and Set funktion
- 2 buttons for optional auxiliary use (e.g switchable extension of C or L)

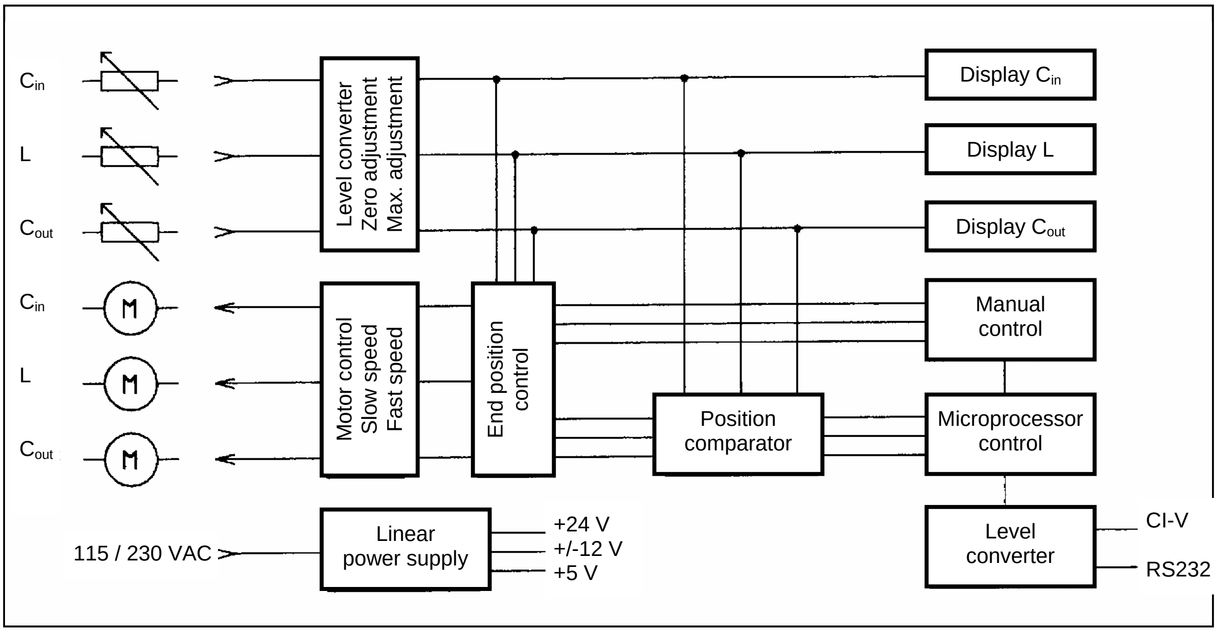

Fig. 2: Block diagram control unit

The electronics are standard technology and mounted on a printed circuit board with solder-stoppers. Showing the whole detailed circuit diagram would be too extensive for this report, so here is a block diagram of its configuration (Fig 2). The blocks are as follows:

- Level converter for the position signals of the network components. This stage also contains zero-point and maximal-value calibration of each component.
- Actual-value logging of the network components. Display of values from both variable capacitors and the roller inductor on each of a 4 digit display, valued between 0.0 and 100.0 (1000 increments)
- End position control over all network components. This is necessary to protect the servos and the feedback potentiometers.
- Position comparison stage for all network elements. Necessary for exact positioning of the matching components during automatic mode.
- Electric servos for all network elements. Motorised movement with crawl and fast gears for precise adjustment. Switching point for crawling and target window for each moving part.

- Illuminated functional keys for perfect manual operation
- Microprocessor for automatic operation, for frequency-dependent adjusting of matching components whether in transmitting or receiving mode. With CI-V interface and components for Icom, and RS232 interface for other transceivers. This as an optional sub-assembly.
- Integrated power supply for 115 or 230 VAC, 50 to 60 Hz.

Fig 3: The control unit

Construction

The antenna matching system comprises two parts, as described: The remote matching unit and its control panel (Fig 3).

The matching unit is fitted in a weather-proof glass-fiber reinforced epoxy housing, so as to be mounted near the antenna terminals, or at the end of the symmetrical feeder line.

The control-unit is in a metal housing. Its usual place is in the shack, where it can be manually operated or can communicate with the transceiver in the automatic mode of operation.

Operational Modes

The SAMS antenna matching system has 3 operating modes:

- Manual operation mode
- Calibration mode
- Automatic operation mode (needs micro processor control)

Manual operation mode

This is the initial status, i.e. after switching on, the unit is always in this mode. In manual mode, all matching elements are adjusted by using the keys, whereby the fast button may be used for quick adjustment of the elements, if needed.

Adjustment takes place at the lowest SWR measurable on the transceiver or SWR meter. Of course, an antenna-analyzer may be used as an indicator, whereby the analyzers from AEA have proved to be especially efficient.

The actual values can be read on the display and a frequency designated and logged on a list.

Calibration mode (needs micro processor module)

The calibration mode is a condition of automatic operation. It requires the extension of the matching system through a micro processor module and a data communiction to the transceiver (CI-V, RS232)

In calibration mode, the system is switched to manual and matching done at best available SWR.

The values reached do not have to be written in the list by hand, but can be saved to a data bank, together with the frequency information, by pressing the set button.

The adjustment values will be saved to the data bank, according to antenna type and frequency steps. The data bank runs automatically in the background.

Automatic operation mode (needs micro processor module)

In automatic operation mode the optimal matching constellation is picked out of the data bank and implemented.

This is done purely frequency dependent and therefore not only in transmitting mode but also simultaneously in receive, which is a pivotal advantage of this system and exceeds all other similar systems known to me!

Any necessary adjustments e.g because of snow or ice on the antenna can be easily done manually and memorized, if required.

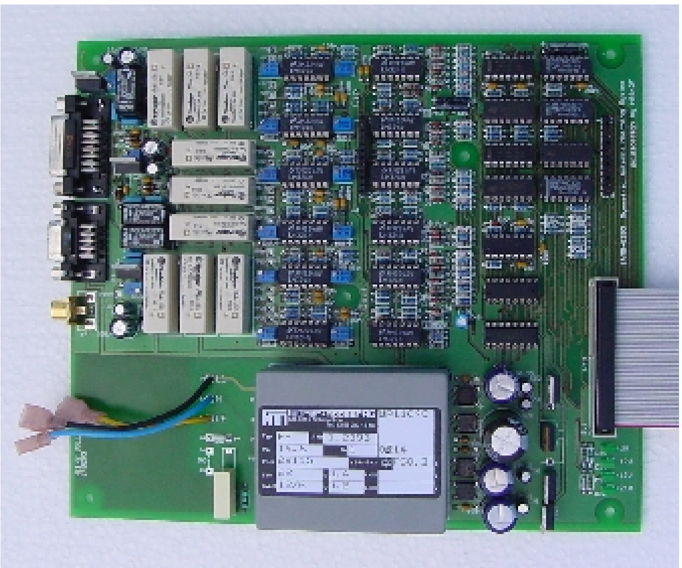

Fig 4: Control board

Fig 5: Matching network

Interested in this innovative solution?

The SAMS antenna matching system described above is a high quality and very comfortable solution, which combines efficiency and ease of use. To bring all the criteria together in one unit, from scratch has taken a lot of research and effort and is probably way outside the capabilities of many radio amateurs.

To make this unit available to as many users as possible, I can offer to all interested ones the possibility to acquire the complete matching network system in nearly every variation – depending on every customers requirements.

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