Innovative Field Receiver Based on a New Type of Active Rod Antenna

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***Abstract*—An innovative approach to improve classical Rod Antennas is here described. This kind of antenna is used in EMC application since many years, but they have intrinsic design limitation and little improvement has been introduced to the design of the antenna in the past decades. Most of the limitation of a classical Rod Antenna can be overcome, thanks to a combination of technical solutions that can transform a rod antenna into a field receiver, yet maintaining the physical dimensions as required by civilian and military standards. An automatic preselector can also be added, as well as a preamplifier and attenuator banks. Moreover, a more convenient fiber optic output can be added as well, to avoid cable couplings and grounding effects.**

***Keywords*—rod antenna; field receiver; grounding effects**

I. Introduction

Since many years rod antennas are used to measure vertically polarized electric field in frequency ranges between 10 kHz (or even less) and 30MHz (and more). These devices are widely used in EMC to measure the radiated emissions of equipment under test, for antennas calibration purposes, for site calibrations and shielding efficiency evaluation, in electromagnetic safety investigation to measure field levels, etc.

Working from VLF to HF, with wavelength from tens of kilometres to tens of meters, a rod antenna can operate in both near and far field regions with highly variable wave impedance. Due to the limited length of the monopole, this impedance is higher than the one typically shown from the other kind of usual antennas, even at the high end frequency of 30 MHz. At lower frequencies the impedance of a classical rod antenna becomes extremely high, being its equivalent model a small capacitor in the order of 10 pF.

Considering an antenna as a transformer operating to match field wave impedances and receiver impedance, the need to manage extremely variable impedance values results in a wide variation of the antenna factor, which could rise up to 100 dB, with the consequence of very high noise floor of the measuring system.

The compromise adopted so far to overcome the above limitation is to connect the rod directly to a high input impedance of an amplifier, realising in this way a tool that is no longer an antenna, rather it is a voltage probe.

With the amplifier, the antenna factor is maintained roughly constant over the operating frequency band, with a sensitivity that anyway remains limited by the noise figure of the amplifier, and with some distortion effects, as typical in active broadband devices.

However, the dynamic range is limited and, moreover, since high impedance input stages of these kind of amplifier are sensitive FET gates, damages are possible and frequent system verification to check they are still operating correctly becomes mandatory.

Due to the above limitations (for more details see next clause), the use of rod antennas is critical in some applications, but on the other hand there are conditions where the electric field E shall be measured (especially in near field conditions), therefore a solution is required.

II. Limitations of Classical Rod Antennas

In the following table a summary of the major limitations usually exhibited by classical rod antennas.

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TABLE I. MAJOR LIMITATION OF A CLASSICAL ROD ANTENNA

Limit	Reason	Remarks
Weakness to transients and high signals	FET based high impedance input stage can be easily damaged	Need of frequent verification, temporarily replacing the rod with a matching network to an external generator to verify the antenna.
No attenuation	Rod antennas do not have automatic variable attenuators	Some antennas accept dedicated manual attenuator at the bottom of the rod.
No gain control	Rod antennas do not have gain control	Some antennas have a switch to manually increase/decrease the gain of the built-in preamplifier.
Easy saturation	Broadband active input stage with no automatic control	Some antennas may have an LED to alert that saturation occurs.
Limited sensitivity	High noise figure of the active stage input stage	High noise floor cannot be eliminated.
Limited dynamic range	Combination of high noise floor and saturation effects	Without automatic attenuator and preamplifier control the dynamic range cannot be increased.
Antenna Factor variation	Self capacitance changes caused by grounding variations	The self capacitance is mathematically defined and it is function of the grounding. The AF is function of the self capacitance.
Resonances of the complete system due to the coaxial cable	The presence of the coaxial cable causes resonances that may result in large deviations from the ideal capacitive behavior of the rod antenna	The effects related to the cable have to be minimized, but they always remain highly unpredictable.
Additional measurement uncertainty	The presence of the coaxial cable causes coupling and grounding variations, and also wave scattering	The effects related to the cable have to be minimized, but they always remain highly unpredictable.

III. INNOVATIVE FIELD RECEIVER BASED ON A NEW TYPE OF ACTIVE ROD ANTENNA

The basic idea is to combine a traditional rod antenna with some circuitries that are typically available only in receivers, to make a rather complex instrument that maintains the basic characteristics of a rod antenna but can be used in many other different applications, as most of the limitations of the classical rod antenna could be eliminated.

The high complexity of the new unit, as it is conceived so far, can be realized at a glance looking at the following indicative block diagram.

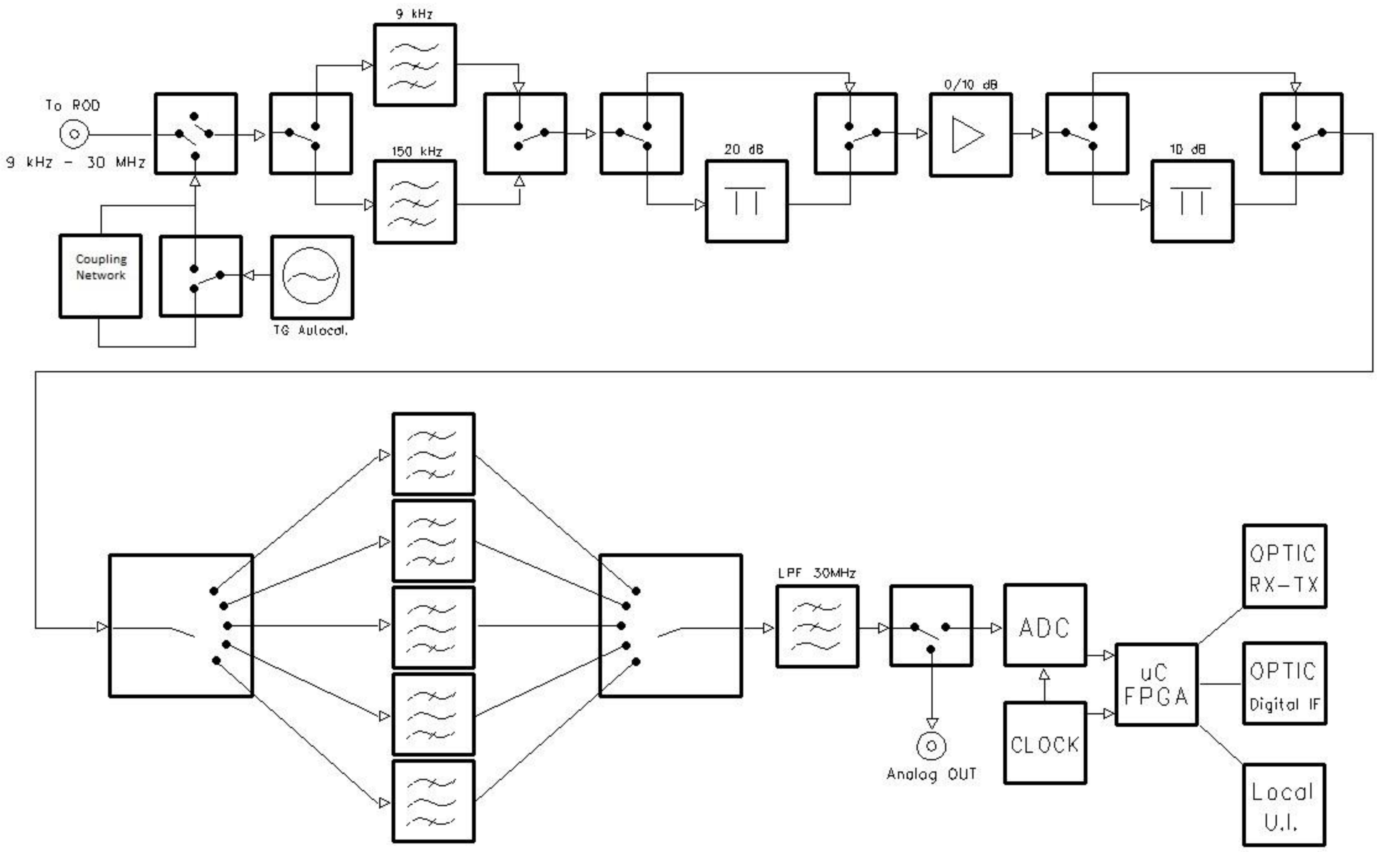

Fig. 1. Block diagram of the Innovative Field Receiver Based on a New Type of Rod Antenna (5 bandpass filters)

To minimize the effects of out of band low frequency disturbances, the input from the rod is first processed through two high impedance high-pass filters that can be chosen to set the lower end at 9 kHz or 150 kHz, depending the need and the standard in use. The signal is then attenuated up to 20 dB, amplified up to 10 dB and attenuated again up to 10 dB, to provide best possible performances in term of saturation level, sensitivity and dynamic range.

After that the signal is preselected with five or six band-pass filters; the following table shows the 6 filters frequency division:

9 kHz	to	150 kHz
150 kHz	to	5,67 MHz
5,67 MHz	to	11,19 MHz
11,19 MHz	to	16,71 MHz
16,71 MHz	to	22,23 MHz
22,23 MHz	to	30 MHz

With this configuration, for a single CW tone the saturation level can be very high (as high as 1000 V/m according to a design model), and even in case of broadband signals the filters and the preselector can dramatically reduce the occurrence of saturation.

The sensitivity that the proposed solution can achieve is outstanding (according the same design model, at least -22 dBμV/m @ 1 MHz and 200 Hz RBW, or even better), while the dynamic range could span from 140 dB to 175 dB, depending the available attenuation.

A revolutionary feature of this innovative Field Receiver is the availability of an internal tracking generator that allows automatic functional verification without any calibration kit. The generator can be connected directly to the antenna or to the receiving unit, or it can be connected to both thanks to a coupling network, so it permits to evaluate the Antenna Factor, to assess the self-capacitance of the antenna and to feed the unit with a known signal, also with immediate feedback on the quality of the grounding and on the repeatability of the set-up.

Although the Field Receiver keeps an output via traditional coaxial cable – a legacy to old measuring solutions - the preferred output is on a Fiber Optic link that, thanks to a dedicated protocol, allows a common serial communication via USB port to a PC (optical-to-USB converter) or to new technology receivers with FO link input.

As this Field Receiver could also act as a traditional rod antenna, the operating frequency range could be 9 kHz to 30 MHz (easily extendable), while the mechanical length of the rod is 100 cm (CISPR 25), that with a removable extension can be increased up to 104 cm (MIL-STD 461). The ground counterpoise will be 60 cm times 60 cm, as required by the standards.

A replaceable Li-Ion battery pack makes easy to operated outdoor and in particular test conditions.

IV. Advantages of Innovative Field Receiver Based on a New Type of Rod Antenna

The previous table 1 is now updated with the advantages given by the proposed new solution:

TABLE II. How the New Type of Rod Antenna Improves the Behaviour of a Classical Rod Antenna

Limit	Reason	Remarks
Weakness to transients and high signals	FET based high impedance input stage can be easily damaged	Automatic self-verification made with built-in Tracking Generator in negligible time.
~~No attenuation~~	Rod antennas do not have automatic variable attenuators	Automatic attenuation available.
~~No gain control~~	Rod antennas do not have gain control	Automatic gain control available.
~~Easy saturation~~	Broadband active input stage with no automatic control	Internal preselector available, that together with automatic control of attenuation and gain, make saturation very unlikely.
~~Limited sensitivity~~	High noise figure of the active stage input stage	The internal preselector, together with automatic control of attenuation and gain, allow lowering the attenuation and increasing sensitivity.
~~Limited dynamic range~~	Combination of high noise floor and saturation effects	The internal preselector, together with automatic control of attenuation and gain, allow increasing dynamic range.
Antenna Factor variation	Self capacitance changes caused by grounding variations	The RF cable replaced by a Fiber Optic link makes the grounding of the counterpoise much more repeatable.
~~Resonances of the complete system due to the coaxial cable~~	The presence of the coaxial cable causes resonances that may result in large deviations from the ideal capacitive behavior of the rod antenna	The RF cable replaced by a Fiber Optic link completely eliminates the effects due to the cable.
~~Additional measurement uncertainty~~	The presence of the coaxial cable causes coupling and grounding variations, and also wave scattering	The RF cable replaced by a Fiber Optic link completely eliminates the effects due to the cable.

V. Prototyping

To make such a new receiving system could be difficult and all over the realization of the project showstoppers may arise. For this reason the selected approach is somehow "modular", following the path of elementary blocks prototyping first, with a subsequent phase of assembly and tuning of all the modules.

With this concept in mind, the filters have been designed and optimized, both the high-pass input filters and the bandpass filters. Experimental results, combined with manufacturing needs, supported the selection of six bandpass filters, that is more convenient in terms of performances, costs and easy manufacturing and calibration.

Military grade switches and attenuators are the right solution for the input section, as performances and reliability are guaranteed in all operating conditions for thousand and thousand of cycles.

A similar switch is also used to connect the antenna to the internal tracking generator, with or without the coupling network: another “brick” of the system capable of delivering enough signal over the entire frequency range of 9 kHz to 30 MHz.

The digital section after the analogue output has been easily tested, and the fiber optic link was chosen among those featuring the highest mechanical resistance (for outdoor operation) at a reasonable price.

The mechanical assembly was not difficult to realize, yet the best compromise in terms of ruggedized construction and flexibility of use took some time to be found.

A receiving system like the one proposed needs a powerful software to supervise all the functions, in particular those related to the use of the internal signal generator to make the “auto-calibration”, to evaluate the Antenna Factor and to assess the self-capacitance of the antenna. Options like remote control of the antenna and a feedback on the quality of the grounding are still under evaluation. This software has been widely tested and is now ready for being implemented on the prototype unit.

VI. CONCLUSIONS

This innovative field receiver is very promising and represents a dramatic step forward compared to traditional rod antennas. The fully comprehensive tests of the prototypes have been already at an advance stage, and so far all the expected performances and characteristics were met. However, improvements and adjustments on the hardware and on the software are still in progress.

Final tests results are expected soon and will be reported.

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