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DEVELOPMENT OF EPR SYSTEMS – SOLUTION OF WROCLAW UNIVERSITY OF TECHNOLOGY

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The paper describes the new designed L-Band EPR spectrometer devoted mainly for testing of irradiated food samples. Some units of the designed spectrometer such as the L-Band microwave unit, digital magnetic field controller, digital EPR signal receiver, small size electromagnet, and loop-gap cavity are very suitable for an advanced upgrade of older type EPR spectrometers.

INTRODUCTION

A group of staff members of the Wroclaw University of Technology, earlier collaborating with company Radiopan have designed completely new units for EPR spectrometers, namely, digital magnetic field sweeper, digital magnetic field controller, digital EPR signal receivers, microwave L-, X- and Q-Band units with built-in microwave frequency counter, very high efficiency electromagnet high power supply (up to 25kVA) with air or water cooling. The new units are very suitable for an advanced upgrade of older type EPR spectrometers as well as for building up a brand new spectrometer. The new units are fully PC controlled via the popular USB interface, which makes possible an automation of EPR experiments. The special computer program *EPR System* for Windows 2000/XP/Vista/Win7 to control of the upgraded spectrometer has been designed. With new units it is possible to build a special EPR spectrometer with two independent receiving channels (1kHz and 100kHz) with two-chamber cavity. A two-channel EPR spectrometer is very suitable for quantitative measurements of intensity in relation to a reference sample. A spectrometer equipped with new units can be controlled using a desktop PC as well as with a notebook computer.

L-BAND EPR SPECTROMETER

Under the Polish research project entitled "**A Prototype of the EPR Spectrometer for Irradiated Food Testing**", a complete L-Band EPR spectrometer has been designed and constructed. The spectrometer is designed mainly for the testing of food irradiation levels. The illustrative diagram and the complete view of the spectrometer is shown in Fig. 1 and 2 respectively.

The designed spectrometer consists of:

1. L-Band microwave unit.
2. L-Band Loop-Gap cavity with the central frequency of 1050 MHz, suitable for measuring of samples with 5mm diameter and 50mm length.
3. Digital 100 kHz EPR signal receiver.
4. Hall Effect digital magnetic field controller which enables synchronous with the magnetic field sweeping recording of the EPR signal.
5. Small size electromagnet with 90mm pole diameter and 38mm measuring air gap and weight of 15kg. The magnetic field induction in the gap is regulated in the range of 0 – 100mT with the sweep range up to 50mT.

The designed spectrometer is fully controlled with the dedicated program *EPR System* (via USB interface).

Although the designed L-Band spectrometer is foreseen mainly for the testing of food irradiation, some units as, e.g., magnetic field controller, digital EPR signal receiver and control program are fully universal and may be used in EPR spectrometer for UHF-, L-, S-, X- and Q-bands, including 2-channel X-Band EPR system.

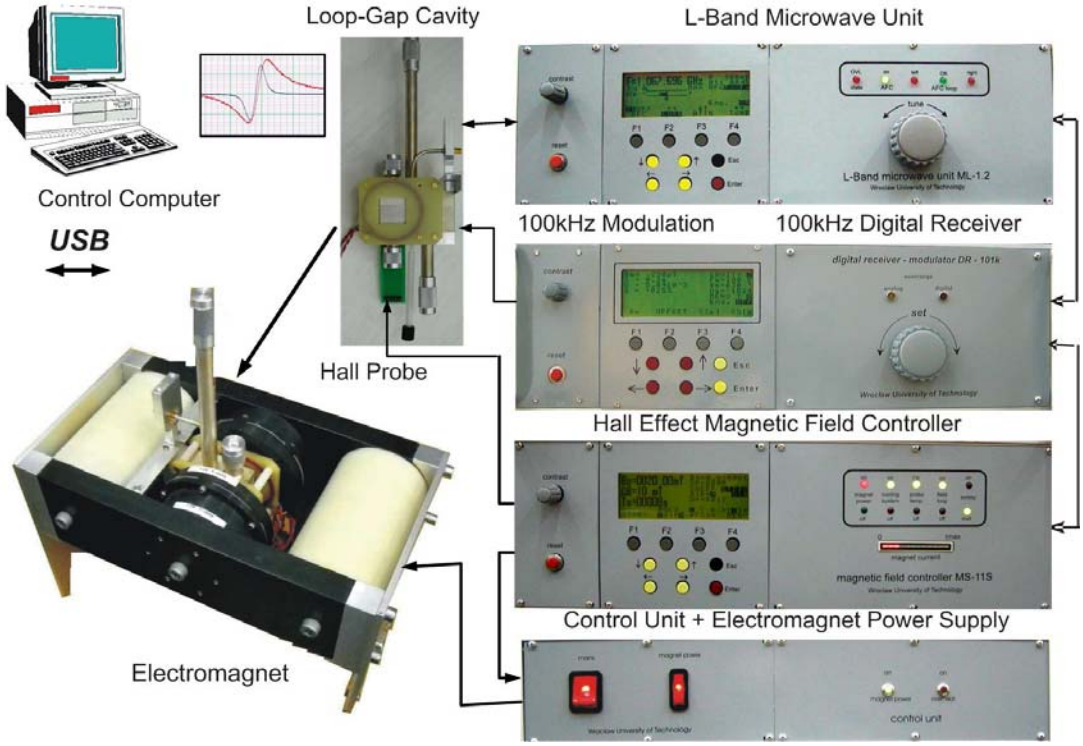


Fig. 1. Illustrative diagram of the L-Band EPR spectrometer designed by our group.

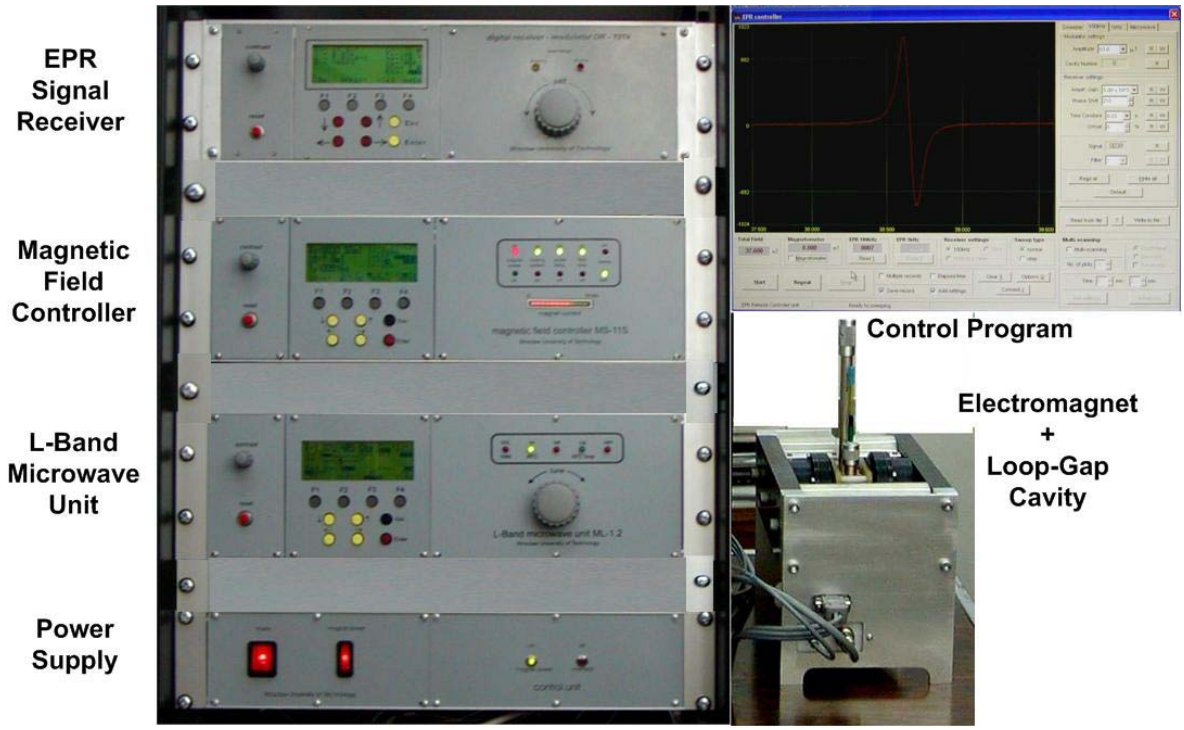


Fig. 2. Complete view of the L-Band EPR spectrometer designed by our group.

X-BAND 2-CHANNEL EPR SPECTROMETER

The X-Band 2-channel spectrometer with a double cavity is excellent for quantitative analysis of different substances via measurements of EPR lines intensity in relation to a reference sample. The block and illustrative diagrams of this EPR spectrometer are shown in Fig. 3 and 4, respectively.

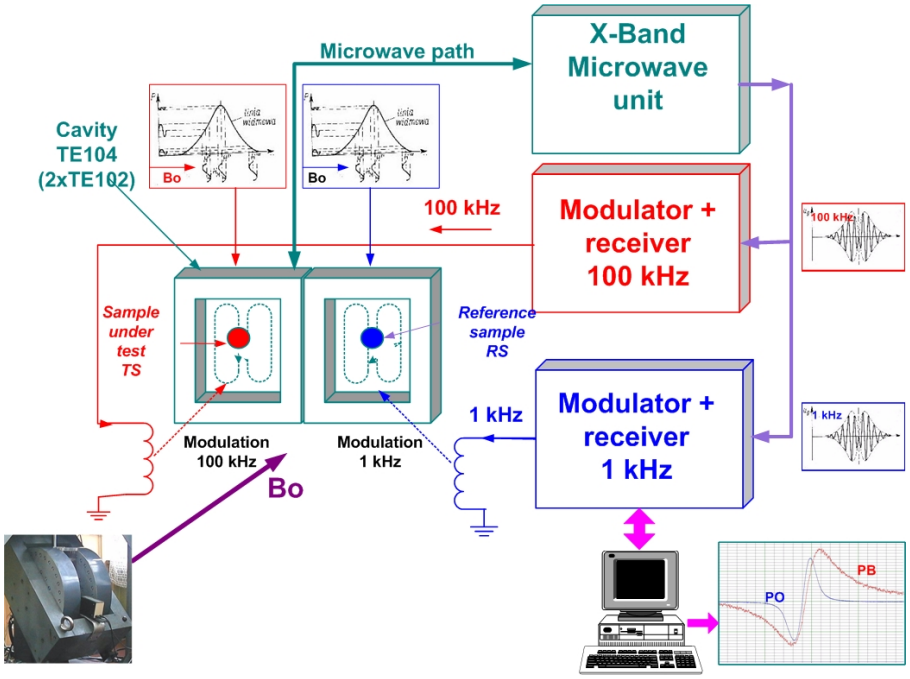


Fig. 3. Simplified block diagram of the X-Band 2-channel EPR spectrometer.

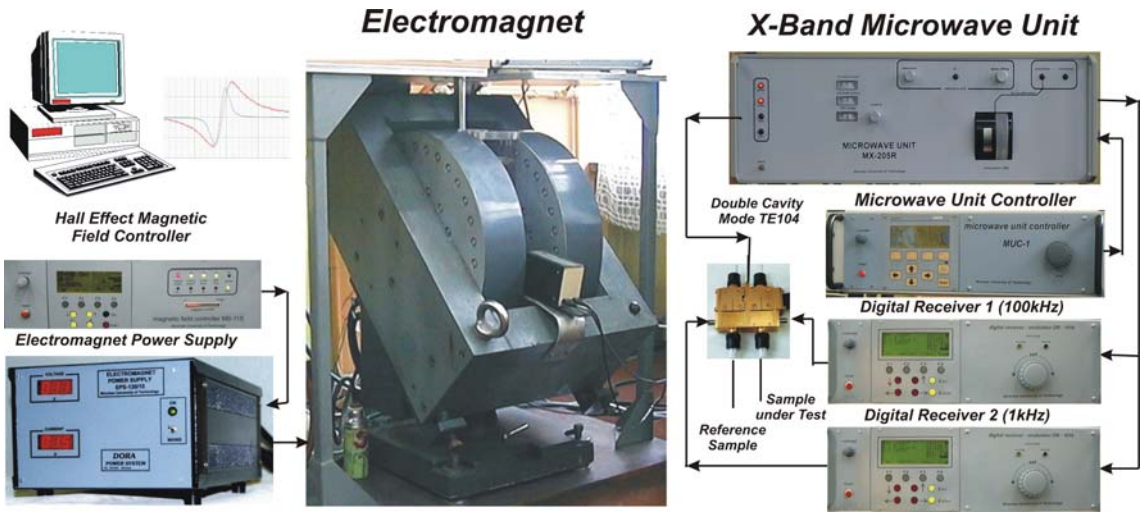


Fig. 4. Illustrative diagram of the X-Band 2-channel EPR spectrometer.

COMPUTER PROGRAM *EPR SYSTEM*

The program EPR System enables a full PC control (via USB interface) of the EPR spectrometer fitted with new units as digital field controller, digital 100kHz/1kHz EPR signal receiver, microwave unit (full control of the new L-Band microwave unit), frequency/power meter (made by Wroclaw University of Technology). Additionally, the program EPR System cooperates with other instruments fitted with typical digital interfaces (USB, RS-232) as NMR magnetometer, temperature controller, frequency counter etc. The main window of the program is shown in Fig. 5.

The most important features of the program:

- setting of conditions of the EPR spectra registration: central magnetic field, magnetic field sweep range, sweep mode, sweep time, 100kHz and 1kHz modulation amplitude, receiver gain, time constant, choice of single or multiple measurement,
- registration of EPR signals with automatic saving of registration conditions,
- single and multiple registration with automatic giving of records names, multiple registration with simultaneous accumulation and averaging,
- advanced mathematical processing of registered spectra: smoothing, integration, differentiation, approximation, multiplying spectra through the constant and through the function etc.

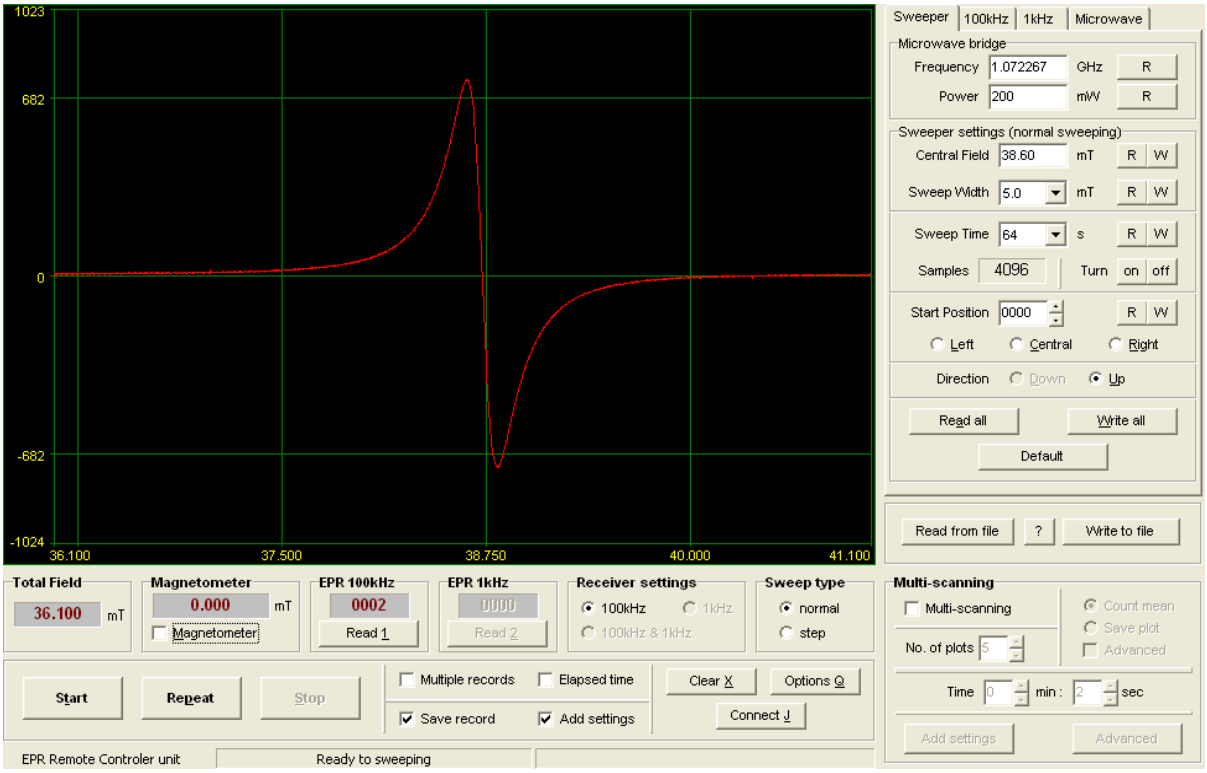


Fig. 5. Main window of the program *EPR System* (L-Band EPR spectrometer controlled)

X-BAND TWO-CHAMBER CAVITY TE104 MODE AND CYLINDRICAL CAVITY TE011 MODE

The TE104 mode two-chamber cavity consists of two identical rectangular TE102 mode cavities. The first chamber (with 100kHz modulation) is intended for the sample under test and the second chamber (with 1kHz modulation) is intended for the reference sample. The amplitude modulation level in both chambers is set independently (Fig. 6a).

The cylindrical cavity TE011 mode with internal hole of 25mm (Fig. 6b) is ideal for temperature measurements. The large internal hole makes it possibly to insert temperature control equipment of a big size.

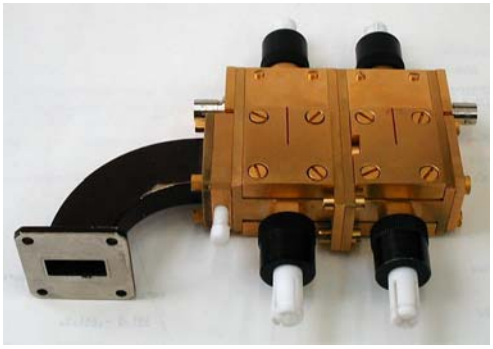
a.  b. 

Fig. 6. Two chamber X-Band rectangular cavity TE104 mode (a) and X-Band cylindrical cavity with hole of 25 mm (b)

MANUALLY CONTROLLED TWO AXIS GONIOMETER

The two axis goniometer (with a very small own signal) makes it possible the changing of the position of sample under test in two axis in respect to magnetic field direction

Fig. 7. X-Band two axis goniometer

X-BAND MICROWAVE UNIT AND MICROWAVE UNIT CONTROLLER (OLDER DESIGN)

The shown X-Band unit is dedicated for replacing of old (Radiopan, Bruker, Jeol) microwave unit or to build a new X-Band EPR spectrometer.

Fig. 8. X-Band microwave unit (older design)

HIGH EFFICIENCY ELECTROMAGNET POWER SUPPLY

The shown high power supply is devoted for replacing of old electromagnet power supply or to build a new EPR spectrometer

Technical data:

Maximal Output Current	400A
Maximal Output Voltage	1000V
Maximal Output Power (1 module) - 5kW (up to 25kW with 5 modules connected parallel))	
Efficiency	> 95%
Supply	3x380 – 3x415V
Cooling	water or air
Dimensions, weight (1 module)	420x270x315, 15kG
Weight/power ratio=<	3kG/kW

Fig. 9. High Efficiency Electromagnet Power Supply.

PORTABLE, HALL-EFFECT MAGNETIC FIELD METER

Technical data:

Range	20, 200, 2000 mT, Auto (DC, AC)
Probes	flat, 1-axis, 3-axis, flux-gate
Interface	USB
Accuracy	<0.2% (DC), <0.5% (AC)

Fig. 10. Portable, Hall-Effect magnetic field meter

FUTURE SOLUTIONS (IN DESIGN)

1. Remotely controlled X- and Q-Band microwave units with built-in microwave frequency and power meter
2. Remotely controlled, 2-axis goniometers for X-Band rectangular and cylindrical (with hole 25mm) cavity
3. „Hybrid magnetic field meter" consisting of NMR and Hall-Effect type magnetic field meters.

SUMMARY

The EPR system designed by our team is an original, multifunctional solution composed of functional segments which can be used for the construction of any desired type of EPR instrument operating in L, X and Q bands. In addition, the system is suitable to be utilized for the remodeling of old type EPR spectrometers which are not in use now. The adaptation of the system makes possible to take advantage of actually useless but valuable microwave elements and magnets of old EPR spectrometers which can be found in numerous laboratories. Both newly constructed and renewed EPR spectrometers based on our system are much more economic solution than the purchase of a new apparatus.

INFORMATIONS

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