Chapter 13

Trends in EPR Technology

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Abstract: A personal view of trends in EPR technology is presented. It is unlikely that the fundamental structure of the field will change, but it will be strongly influenced by the rapid increase in computer power, digital storage, and signal processing capability. In the author's laboratory current themes are resonator enhancement by electromagnetic field finite element modeling, analysis of noise, and digital detection and acquisition of data at multiple microwave frequencies. Some trends foreseen are (1) optimization of resonators for ultra-small samples; (2) step-recovery pulse EPR in which the initial conditions may be established by a step in some experimental condition such as light level or nuclear frequency irradiation; (3) blurring of the distinction between pulse and CW EPR as temporal changes in the resonant condition of a “CW” measurement are changed in times of the order of spin relaxation times; and (4) increased use of ELDOR.

1. INTRODUCTION

The EPR field is composed of a large number of application areas, each with a small number of active participants. The systems manufacturers produce flexible general purpose spectrometers with numerous accessories in order to serve this fragmented market. Although EPR spectroscopy is a fundamental measurement tool that will remain active indefinitely, and although there will continue to be inventions, discoveries and new applications, it is unlikely that the fundamental structure of the field will change. EPR will continue to be used for research in physics, chemistry and biology to examine samples in the liquid, solid and gas phases over a range of temperature and other conditions.
From its earliest days, the underlying technology was based on military developments in radar. In recent years, computers, cellular telephone technology and advances in digital devices have become increasingly important in contributing to the technological foundation of EPR spectrometers.

This reality – that our field is relatively small and dependent to a considerable degree on technology from larger scale development activities – places constraints on future progress of the field. The fundamental technological event of our times is rapid increase in computing power and the performance of associated digital and mass storage devices. Our future, from a technological perspective, will be based on this fact. Advances in EPR digital detection, in data capture and storage as well as in use of advanced signal processing methods are discussed in the chapter on digital detection (see Ch. 7).

Even though EPR instrumentation is strongly dependent on technology developed in other fields, there are areas where the special constraints of EPR have led to significant technological advances. Some of these are discussed below.

2. RESONATORS

Basic contributions to EPR technology that have been developed from within the EPR discipline include resonator development. The requirements of sample access, variable microwave coupling, resonators free from impurities, wall penetrability by high frequency field modulation, temperature control, etc. place constraints on resonator design that we ourselves must face – there is little in the way of technology to borrow from other fields. It is appropriate for the EPR instrumental futurist to predict advances in those specific areas where we control the technology and an attempt is made here.

The Varian multipurpose cavity oscillating in the rectangular TE_{102} mode served as the default EPR resonator for many years. See Rempel et al. (1964) and Hyde (1995) for details on the design. This structure was designed to enable a number of specialized EPR experiments as follows: i) light irradiation, ii) dewar insert for flowing temperature controlled gas, iii) dewar insert for liquid nitrogen, iv) so-called “flat cells” for aqueous samples, v) flat cells for tissue samples, vi) a mixing chamber geometry for stopped and continuous flow EPR, and vii) an electrochemical cell. A collet system was developed to support the dewars, flat cells, and sample tubes of various sizes. Two cavity bodies were bolted together to form the dual sample cavity (Hyde, 1965a) oscillating in the TE_{104} mode in order to