MEASURING SUPERWEAK MAGNETIC FIELDS OF BIOLOGICAL OBJECTS IN A NON- SHIELDED ROOM

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IN THE LAST DECADE, THE MEASUREMENTS OF SUPERWEAK MAGNETIC FIELDS OF BIOLOGICAL OBJECTS AIMED AT DERIVING NEW OR ADDITIONAL INFORMATION ON FUNCTIONING OF THE OBJECTS AND ON THE CHANGES THEREIN WHEN AFFECTED BY VARIOUS FACTORS HAVE HAD A REVIVAL OF INTEREST AMONG AND HAVE BEEN USED MORE AND MORE EXTENSIVELY BY THE RESEARCHERS.

THE DEVELOPMENT OF THE GIVEN NEW METHOD OF RESEARCH WAS INITIATED BY THE ADVENT OF NEW HIGH- SENSITIVITY MAGNETOMETRIC DEVICES WHICH INCLUDE, IN PARTICULAR, THE SMALL-BASE QUANTUM GRADIENTOMETER DESIGNED AND TESTED AT THE QUANTUM MAGNETOMETRY LABORATORY OF THE IZMIRAN.

THE QUANTUM GRADIOMETER HAS BEEN FEATURED BY ITS ABILITY OPERATING AT ROOM TEMPERATURES AND IN INTERVAL /20-60 MKT/ OF EARTH'S MAGNETIC FIELDS AT A LOW LEVEL OF INTRINSIC NOISE WITHOUT USING ANY EXPENSIVE SHIELDED ROOMS AND PURPOSEFUL PROTECTION AGAINST THE NATURAL VARIATIONS OF THE EARTHS MAGNETIC FIELDS AND AGAINST DISTANT INTERFERENCE FROM INDUSTRIAL ENTERPRISES, AS WELL AS OF MEASURING THE INDUCTION OF SUPERWEAK MAGNETIC FIELDS OF SAME 1-2 PT.

THE QUANTUM GRADIOMETER IS AN ALTERNATIVE TO THE SUPERCONDUCTING QUANTUM INTERFEROMETER WHOSE HIGH SENSITIVITY CAN BE REALIZED ONLY AT THE TEMPERATURE OF EXPENSIVE LIQUID HELIUM IN A SHIELDED ROOM.

THE SMALL- BASE QUANTUM ORADIOMETER / 5CM / MAKES IT POSSIBLE TO MEASURE THE GRADIENT OF THE MAGNETIC FIELD INTENSITY MODULUS BETWEEN TWO SENSORS, OR THE PROJECTION OF THE MAGNETIC FIELD OF AN EXAMINED OBJECT ON THE EARTH'S MAGNETIC FIELD VECTOR AT A MEASUREMENT POINT. BESIDES, THE COMPONENTS OF THE MAGNETIC FIELD OF AN OBJECT CAN BE MEASURED BY VARYING THE POSITION OF THE OBJECT RELATIVE TO THE EARTH'S MAGNETIC FIELD INTENSITY VECTOR.

PHYSICALLY, THE OPERATIONS OF THE MAGNETOSENSITIVE SENSORS OF THE GRADIENTOMETER ARE BASED ON THE METHOD OF OPTICAL PUMPING AND MAGNETIC RESONANCE IN VAPORS OF AN ALKALI METAL (CESIUM).

IN TURN, THE METHOD IS BASED ON THE WELL KNOWN ZEEMAN EFFECT OF FREE ATOMS WHICH CONSISTS IN THAT THE ENERGY LEVELS OF ATOMS IN A MAGNETIC FIELD GET SPLITTED INTO SOME SUBLEVELS. IN THIS CASE THE ENERGY DIFFERENCE BETWEEN TWO NEIGHBORING ZEEMAN SUBLEVELS IN PROPORTIONAL TO THE INDUCTION OF EXTERNAL MAGNETIC FIELD AND, THEREFORE, CAN BE USED TO MEASURE THE

LATTER.

THE BLOCK DIAGRAM OF THE INSTRUMENT CONSISTS OF THREE SIMILAR-TYPE MAGNETOSENSITIVE SENSORS, OF WHICH TO ARE CONNECTED IN THE DIFFERENTIAL CIRCUIT FOR DISCRIMINATING THE VALID SIGNAL BY THE PHASE-FILTER TECHNIQUE. THE THIRD SENSOR GENERATES A REFERENCE SIGNAL. THE REFERENCE SENSOR HAS BEEN DESIGNED ON THE BASIS OF SELF-OSCILLATION CIRCUIT AND EXHIBITS BROAD-BOUND PROPERTIES. THE GENERATION FREQUENCY OF THE REFERENCE SENSOR IS DEFINED BY THE MAGNETIC RESONANCE CONDITION AND FOLLOWS THE EARTH'S MAGNETIC FIELD VARIATIONS. A RADIO FIELD IS FED TO THE METERING SENSORS (RESONANCE FILTERS) FROM THE REFERENCE SENSOR TO PRODUCE A MAGNETIC RESONANCE IN THE FORMER. THE OPTICAL PUMPING TO THE TREE SENSORS IS FROM A SINGLE SPECTRAL LAMP, THEREBY ENSURING A HIGH DEGREE OF CORRELATION OF INSTRUMENTAL NOISE IN ALL THREE CHANNELS. THE SIGNALS FROM EACH PAIR OF SENSORS ARE SUPPLIED TO THE PHASE-METERING DEVICES WHOSE OUTPUT VOLTAGE IS AMPLIFIED BY FINAL AMPLIFIERS.

THE MEASURED MAGNETIC FIELD IS RECORDED BY A SUITABLE RECORDING DEVICE (OSCILLOGRAPH, RECORDER, FM TAPE RECORDER, ETC.) CONNECTED TO THE FINAL AMPLIFIER OUTPUT. THE VALUE OF THE MEASURED MAGNETIC FIELD IS COMPARED WITH AN EXPLICITLY-KNOWN VALUE OF CALIBRATION SIGNAL.

THE CALIBRATION SIGNAL IS FED TO THE A RADIO-FREQUENCY COIL OF THE ONE OF THE SENSORS FROM THE 50 PT 7 HZ IMPULSE GENERATOR.

IN THE ABSENCE OF A MAGNETIC FIELD GRADIENT BETWEEN THE SENSORS, THE RESONANCE FREQUENCY OF THE REFERENCE SENSOR COINCIDES WITH THE CENTERS OF THE RESONANCE LINES OF THE METERING SENSORS, WHILE THE PHASE SHIFT BETWEEN THE SENSOR SIGNALS IS ZERO.

IF, HOWEVER, THE MEASURING SENSORS ARE AFFECTED BY A LOCAL MAGNETIC FIELD, THE REFERENCE SENSOR FREQUENCY REMAINS INTACT, BUT THE PHASE SHIFT BETWEEN THE SENSORS CHANGES IN PROPORTION TO THE LOCAL INCREMENT OF THE MAGNETIC FIELD.

THE QUANTUM GRADIENTOMETER RESOLUTION IS DEFINED BY THE LEVEL OF INSTRUMENTAL NOISE OF THE SENSORS.

TO MAINTAIN A HIGH SENSITIVITY OF MEASUREMENTS IN THE PRESENCE OF INTERFERENCE AND OF RANDOM GRADIENTS, THE QUANTUM GRADIENTOMETER CIRCUIT IS PROVIDED WITH ADDITIONAL MEANS TO SUPPRESS NOISE BY USING A DETECTOR OF MAGNETIC FIELD VARIATIONS IN THE FIELD STABILIZATION SYSTEM WITHIN THE VOLUME OF MAGNETOSENSITIVE SENSORS.

THE CIRCUIT INTERFERENCE ARE REDUCED BY INTRODUCING A SYSTEM OF SYNCHRONOUS REJECTOR FILTERS IN THE BLOCK DIAGRAM OF A FINAL AMPLIFIER.

THE MAGNETIC FIELD MEASUREMENTS REDUCE TO PLACING AN OBJECT TO BE EXAMINED NEAR (AT 0,3 - 0,5 CM) ONE OF THE SENSORS AND RECORDING THE OUTPUT SIGNAL WITH A RECORDER.

THE VALUE OF THE MAGNETIC FIELD MEASURED IS FOUND BY COMPARING THE MEASURED VALUE WITH THE REFERENCE SIGNAL. THE INSTRUMENT CONSISTS OF TWO UNITS, NAMELY, A UNIT OF SENSORS AND AN ELECTRONIC CIRCUIT UNIT.

THE BASIC SPECIFICATION OF THE QUANTUM GRADIENTOMETER:

1. THE INSTRUMENT OPERATES IN MAGNETIC FIELDS RANGING FROM 25000 NT TO 65000 NT.
2. GRADIENTS ARE MEASURED WITHIN 0-10 PT.
3. TEMPERATURE LIMITS OF THE INSTRUMENT OPERATIONS ARE +18C - +30C.
4. THE INTRINSIC NOISE LEVEL IS 2-3 PT IN THE 0,1 - 35,0 HZ FREQUENCY BAND.
5. THE BASE DISTANCE BETWEEN THE MEASURING SENSORS IS 5 CM.
6. THE POWER CONSUMED DOES NOT EXCEED 35 W.
7. SUPPRESSION OF INTERFERENCE FROM THE MAINS IS AT LEAST 60 DB.
8. THE WEIGHT OF THE SENSOR UNIT IS 2 KG; THE WEIGHT OF THE ELECTRONIC CIRCUIT UNIT IS 7 KG.

THE MEASUREMENTS OF THE MAGNETIC FIELDS OF A MAN BY SMALL-BASE QUANTUM GRADIENTOMETER HAVE DEMONSTRATED THAT THE INSTRUMENT CAN SAFELY AND READILY MEASURE NOT ONLY THE VARIABLE BIOMAGNETIC FIELDS

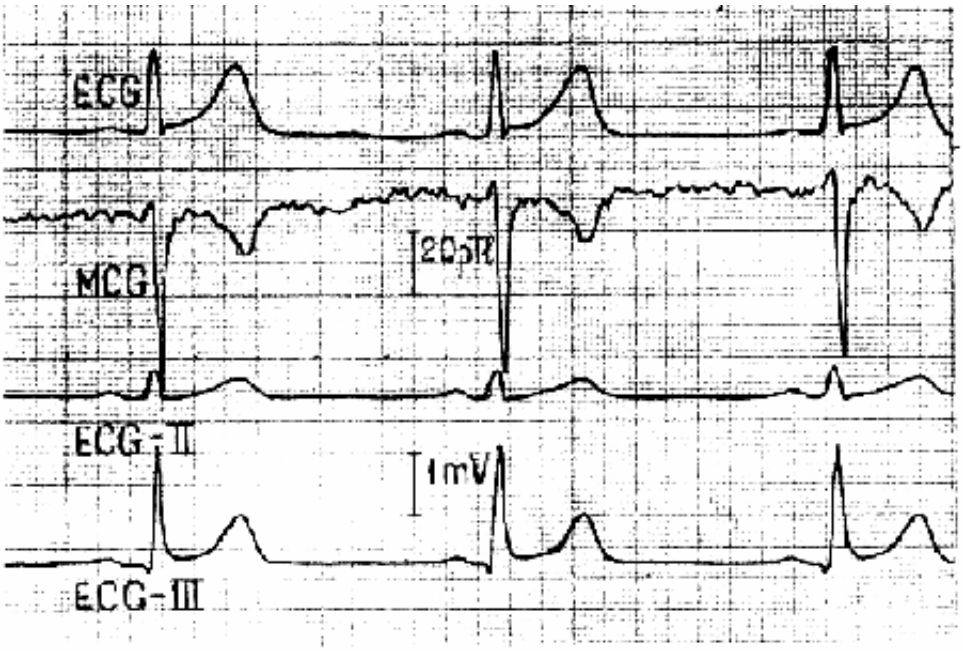

FIG.1 SIMULTANEOUS ECG AND MCG RECORDINGS: MEASUREMENTS AT THE SAME POINT OF A NORMAL SUBJECT.

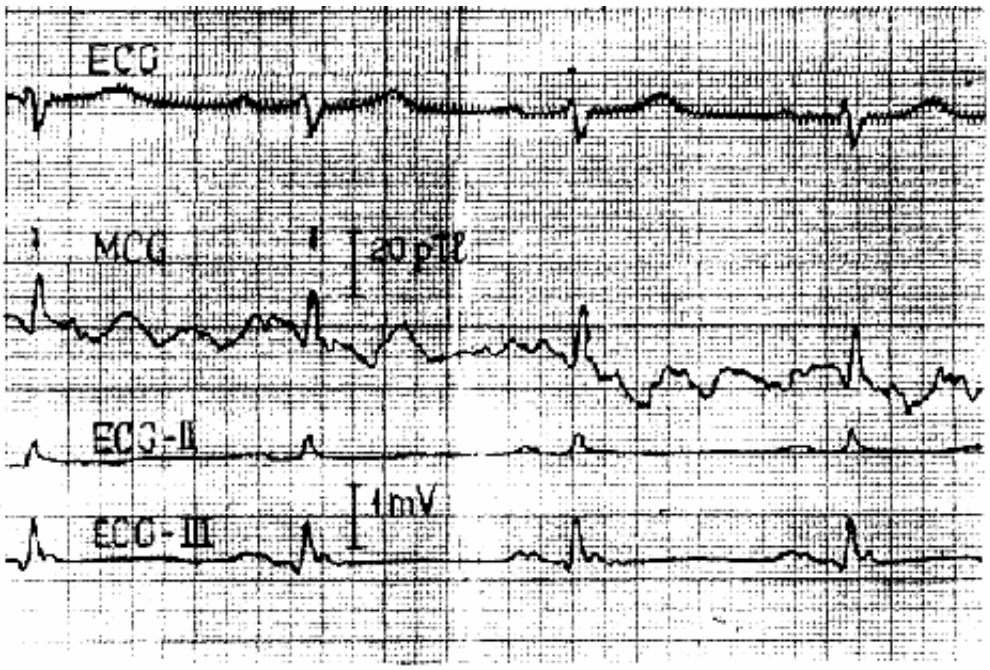

FIG.2 SIMULTANEOUS ECG AND MCG RECORDINGS: MEASUREMENTS AT THE SAME POINT OF AN ABNORMAL SUBJECT.

FIG.3 THE MAGNETOMIOGRAM RECORDING OF HAND'S MUSCLE.

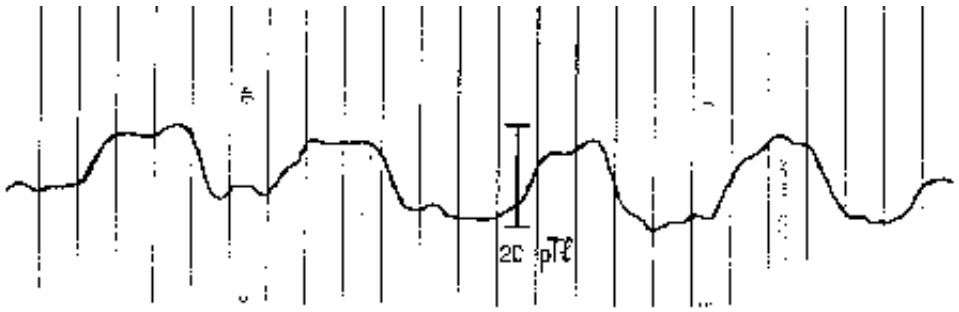

FIG.4 THE MAGNETOOCULOGRAM RECORDINGS OF THE OPENED AND CLOSED HUMAN EYE

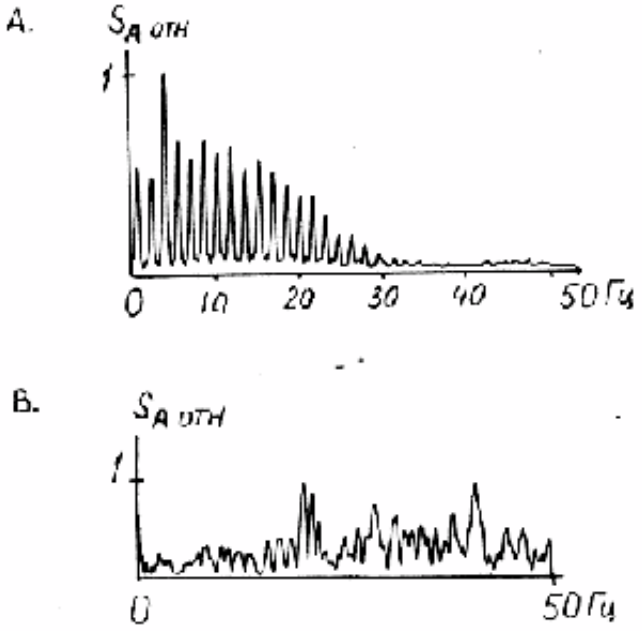

FIG.5 EXAMPLES OF MAGNETIC FIELD SPECTROGRAM OF A NORMAL HEART /A/ AND A HAND'S MUSCLE. /B/.