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SACLANT ASW
RESEARCH CENTER

AN IMPROVEMENT IN THE DESIGN OF THE TOWED NUCLEAR SPIN MAGNETOMETER

by

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1 June 1963

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VIALE SAN BARTOLOMEO, 92
LA SPEZIA, ITALY

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APPROVED FOR DISTRIBUTION

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Director

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In May 1961, The Center took delivery of a towed nuclear spin magnetometer manufactured by Bruce Peebles Ltd. of Edinburgh, Scotland. The original system was designed at the Department of Geophysics, Cambridge, and a description has been given by Hill.[1]

The towed "fish" consists of two parts: a detector unit which houses a polarizing detector coil surrounding a sample of water (referred to as the "bottle"), and a preamplifier unit containing a transistorized tuned amplifier, a bank of tuning condensers, a uniselector, and three switching relays. The two units are connected by a 20 ft. length of twin-core cable supported by a nonmagnetic stainless steel wire. The towing cable, connected to the preamplifier unit, is a 1000 ft length of polyvinyl chloride sheathed screened cable containing 6 conductors and 1 steel core.

Briefly, the mode of operation is as follows. Every 30 seconds a current of about 1 amp is passed through the polarizing coil surrounding the sample of

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[1] Hill, M.N. "A Ship-borne Nuclear-Spin Magnetometer," Deep Sea Research, Vol. 5, 1959, pp 309-311.

water. The relatively strong polarizing field causes a number of the protons in the water to align themselves in the direction of the field. When the field is removed the protons precess around the direction of the earth's magnetic field vector with a frequency proportional to its strength. A voltage, alternating at the precessional frequency, is induced in the detector coil by normal electromagnetic action. The signal, which is of the order of a few microvolts, is amplified in the preamplifier which has very selective tuning. The amplified signal then passes to the tuned amplifier on the ship. The remainder of the circuitry on the ship is designed to measure the frequency of the signal to 1 part in 100,000 and to record a "count" both graphically and on paper punch-tape.

To ensure a good performance from the instrument, two requirements which must be satisfied are:

1. A clean, quick switching off of the polarizing current ensuring a sharp collapse of the applied field.

2. A suitable narrow tuning in the amplifiers of the system to reduce noise.

These requirements were met in the Peebles model by:

a. A suitable combination of switching relays and diodes contained in the preamplifier unit.

b. A tuned preamplifier with narrow band-pass with provision for changing the value of the tuning condenser by means of a uniselector. Thus, if the value of the earth's field changed so as to significantly shift the precessional frequency outside the range for which the amplifier was tuned,

then another tuning condenser could be chosen by remote control from the ship.

During the period May 1961 to November 1962, several surveys were completed using this system. In general the instrument behaved reasonably well with an estimated 95% reliability of operation. Nearly all of the breakdowns which occurred were the result of recurrent noise generated in the towed unit. Various small modifications to the uniselector, preamplifier, and switching relays were tried in an effort to eliminate the source of noise, but these had only limited success.

Finally, at the end of 1962, it was decided to design a new preamplifier, eliminating, as far as possible, all mechanical parts. The results of this experiment were surprisingly successful.

Tests were conducted to see if it were possible to transfer the switching relays from the fish to the ship. The main problem was how then to reduce quickly the polarizing field in the bottle in the presence of large transients caused by the long length of high-capacity cable. Eventually, a solution was found by including a suitable arrangement of diodes in the preamplifier circuit (Fig. 1). The switching waveform, as seen on an oscilloscope, is shown in Fig. 2. The total collapse time of 11 ms is about twice as long as that achieved by the firm but this does not appear to impair performance.

A simplified 4 transistor preamplifier was constructed to replace that of the firm. It has the following characteristics:

1. <u>With the detector coil excluded</u>

   Input signal applied to point A. Total voltage gain 14,000 (83 db). With point A earthed, noise level measured at B = 10 mv. Maximum

amplification occurs at 2400 cps falling by 3 db at 1900 cps and 3600 cps.

2. With the coil included

Maximum amplification occurs at 2000 cps falling by 3 db at 1500 cps and 3650 cps. This band covers a frequency range corresponding to the range of total field values over most of the earth.

The new unit contains only this preamplifier. Fine tuning is no longer used in the fish but is now confined to the main amplifier on the ship.

Although the new preamplifier will pass more noise than the old system, the removal of all "moving parts" and the use of a very compact and simple circuit are thought to have reduced the production of spurious noise. Also, because the new system is smaller and contains no magnetic relays, there is no longer any need to have two separate towed units.

If a 6 volt battery is included in the fish, then the former 6 conductor cable can be substituted by a screened twin-core cable with stress core. Alternatively, using another conductor, the battery supply can be carried on the ship.

The improved system has been used successfully during two cruises this year covering a total of 4 weeks recording. No time has been lost due to breakdowns. The signal to noise ratio, even in very rough seas, has not fallen below 30:1.

A photograph of the improved system together with the old system is shown in Fig. 3.

ACKNOWLEDGEMENTS

The authos would like to express their gratitude to Dr. C. Lister for many helpful discussions.

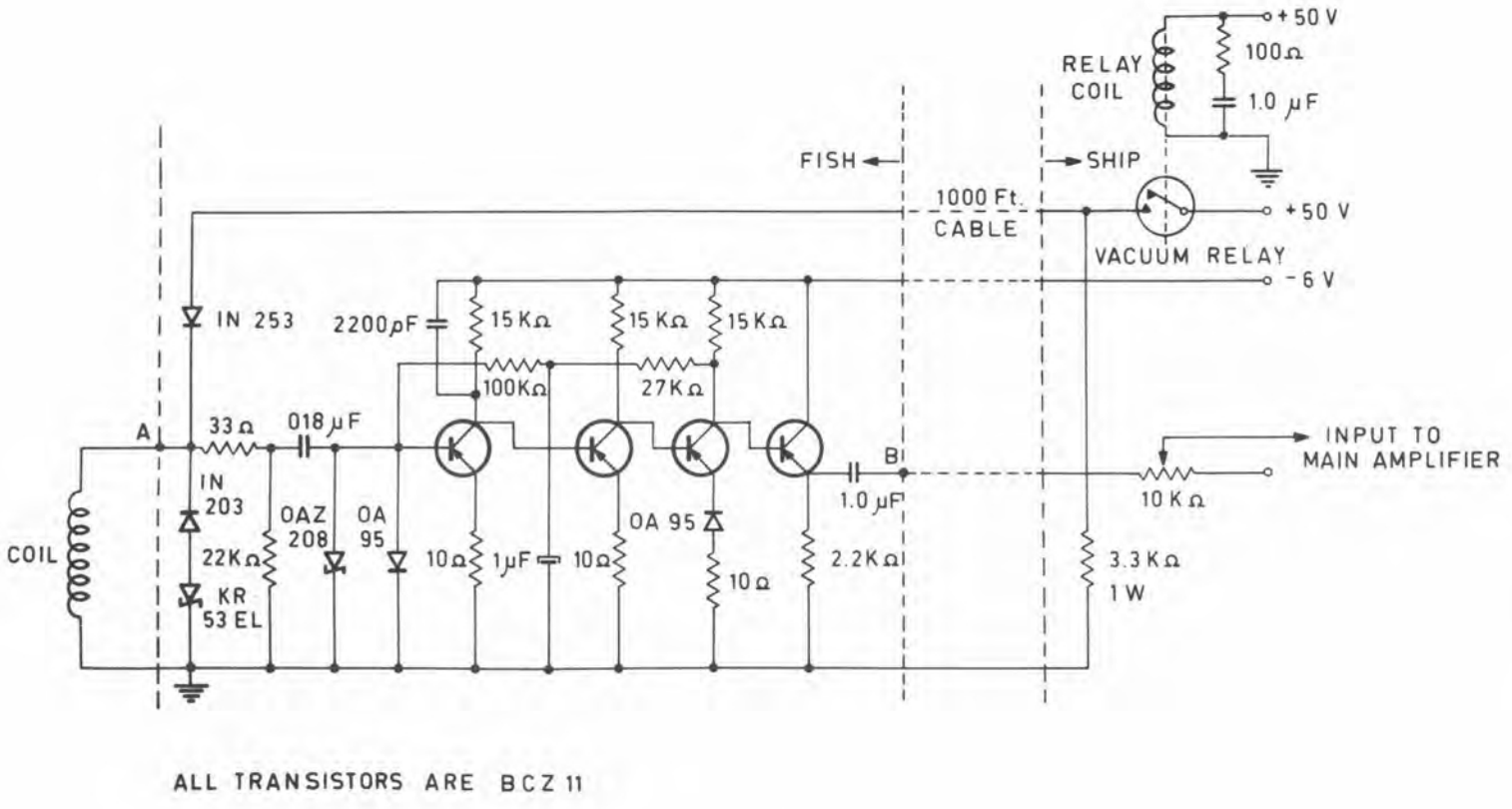

Fig. 1

CIRCUIT DIAGRAM OF MAGNETOMETER PREAMPLIFIER

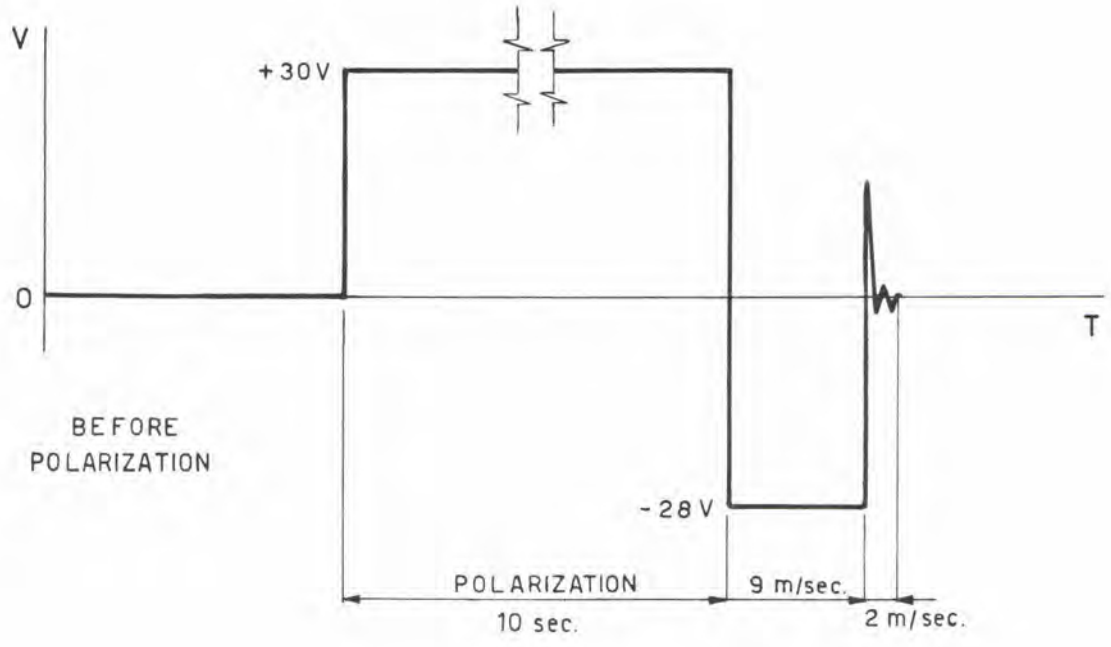

Fig. 2

WAVE SHAPE AT POINT A

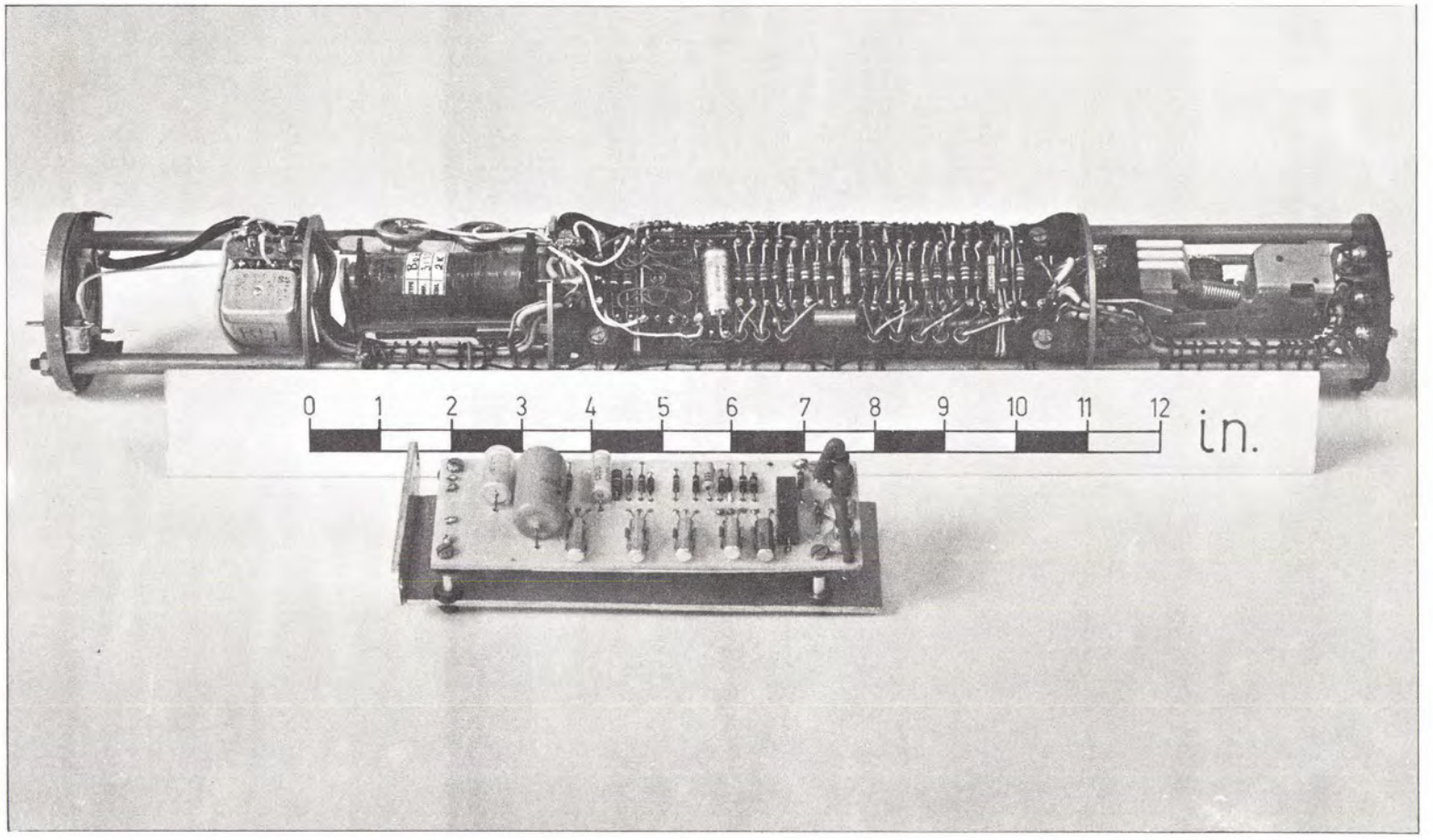

Fig. 3

THE NEW PRE-AMPLIFIER (FOREGROUND) TOGETHER WITH THE MODEL WHICH IT REPLACED

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