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SMALL TRANSISTORIZED RECEIVING ANTENNAS FOR RADAR-MEASUREMENTS IN SALT DEPOSITS

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1. Introduction

As a supplement to seismic diffraction methods an electromagnetic RADAR has been proposed for the investigation of boundaries and inhomogenities in salt deposits /1,2,3/. Salt desposits in general are composed of discrete layers of electrically slightly different materials, as rock-salt or potash for example. The differences mainly concern the permittivity of the various materials. Further discontinuities are geophysical faults, thin layers of basalt or clay, or the outer boundaries of the salt dome itself. For a most effective working of the mine one gradually tries to determine the structure of the deposit from the worked cavities inside the salt dome.

Fig. 1 schematically describes the method proposed in /4/. It uses a transmitter which produces a burst of about five full waves of a frequency adjustable between 50 and 100 MHz and a peak power of about 100 W. This burst is radiated with the help of a dipole transmitting antenna. Reflections caused from discontinuities are received from the receiving antenna and can be observed on the screen of an oscilloscope after amplification. As the permittivity of the surrounding material is well known the delay time of the received pulses can be used to calculate the distance of the reflector.

This paper describes a transistorized direction finding receiving antenna with the help of which reflectors can be detected up to distances of about 1000 m. The accuracy of the direction finding is about 2^{o}.

2. Principle of the receiving antenna

At first the use of passive receiving antennas has been tried. Two pairs of antennas with adcock and cardioidal receiving patterns respectively were mounted alternately to find the position line (adcock) and the $0^{o}/180^{o}$ decision (cardioide). No simultaneous operation of the antennas was possible due to the mutual coupling of the low impedance terminated antennas. Further difficulties arose from the narrow-band behaviour of the differential transformers within the pattern forming networks. On this account a transistorized receiving antenna has been developped which avoids the disadvantages mentioned above.

The geometrical arrangement is sketched in Fig. 2. Four dipole antennas are mounted on one mast via four branches. Low noise transistor amplifiers with high input impedance are directly connected to the terminals of all antennas. Because of the high load impedance the antenna rods are nearly currentless. On this account the coupling of the both antenna pairs is small enough for a simultaneous operation without mutual influences.

The outputs of the antennas 1 and 2 are combined to a cardioide pattern and the outputs of the antennas 3 and 4 are combined to an adcock pattern as indicated in Fig. 2. The corresponding schematic diagram is shown in Fig. 3. The subtraction of the signals in both antenna pairs is not achieved with the help of differential transformers as usually done. In contrast to the common technique each antenna amplifier is provided with two outputs the voltages of which are of equal amplitude but of 180° phase difference. Using always the proper outputs the combining circuit only needs adding networks. This adding of signals easily can be done with broadband resistive networks.

Fig. 4 shows the principle of the antenna amplifiers. Two Darlington-Transistor circuits are working in a push-pull arrangement. The DC-emitter current I_{CO} is supplied with the help of a highly resistive current source (transistor circuit). The magnitude of the input impedance of this amplifier is about five times as high as the source impedance of the antenna. Thus a noticeable reduction of the internal antenna currents and the mutual antenna coupling has been achieved.

The common-mode rejection of the amplifier is about 36 dB through the full operating frequency range. With the passive antennas this value could not be obtained. On this account the transistorized antenna can be used in a smaller distance to the irregular salt-walls in the mine. This is useful for the decrease of declinations due to edge effects of the cavity.

The collector outputs of both halves of the push-pull circuit are fed to the combining network. With the help of this circuit the negative antenna voltages can be taken broadband from the transistorized antennas without the help of transformers. The ratio $\underline{k}_1/\underline{k}_2$ of the voltages in Fig. 4 describes the voltage inversion performance of the amplifier. Values of less than .2 dB in magnitude (magnitude error) and less than 1° in phase (phase error $\Delta\varphi$) over a frequency range from 5 through 200 MHz could be achieved. As the declination $\Delta\alpha$ in the adcock direction finding (for discrete frequencies) is given from the phase error $\Delta\varphi$ by

$$\Delta\alpha = \arcsin \frac{\Delta\varphi}{2\pi d/\lambda_0}$$

this error leads to values of $\Delta\alpha \approx 0.6^\circ$ at the lowest frequencies in use.

The principle of the two adding amplifiers within the voltage combining network is shown in Fig. 5. Transistor T1 operates as common-base amplifier. Its low input impedance of about 2 ohms at the chosen DC-collector current prevents retroactions between the two connected antenna amplifiers. The two resistors Z_c are well adjusted for an exact match termination of the connecting lines under consideration of the transistor input impedance.

3. Measurements

The antenna has been tested in various salt deposits and compared to former passive antennas. The transistorized antenna showed lower influence from the environ, better zeros of both, the adcock and the cardioide pattern, and the possibility of a simultaneous operation of both diagrams. The broadband behaviour of the transistorized antenna covers all carrier frequencies which are in use until now. A change of the carrier frequency of the transmitter does not cause any necessary changes at the receiving antenna.

Fig. 6 shows an example of a received pulse from a reflector in a distance of 860 m. The photograph is double exposed and describes the received voltages with the antenna axis aligned to the reflector (track 3: adcock zero, track 4: cardioide maximum) and counter-aligned, respectively (track 1: adcock zero, track 2: cardioide zero).

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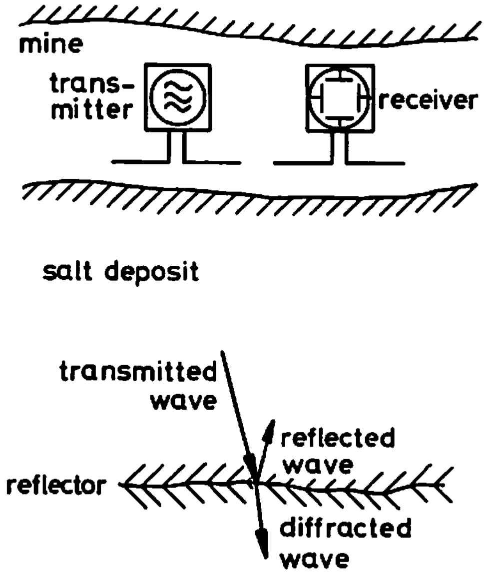


Fig. 1: Geophysical RADAR

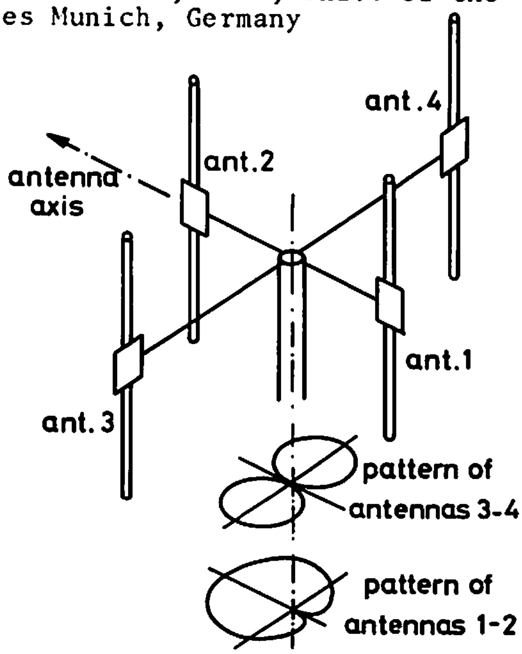


Fig. 2: Basic arrangement of the DF-receiving antenna

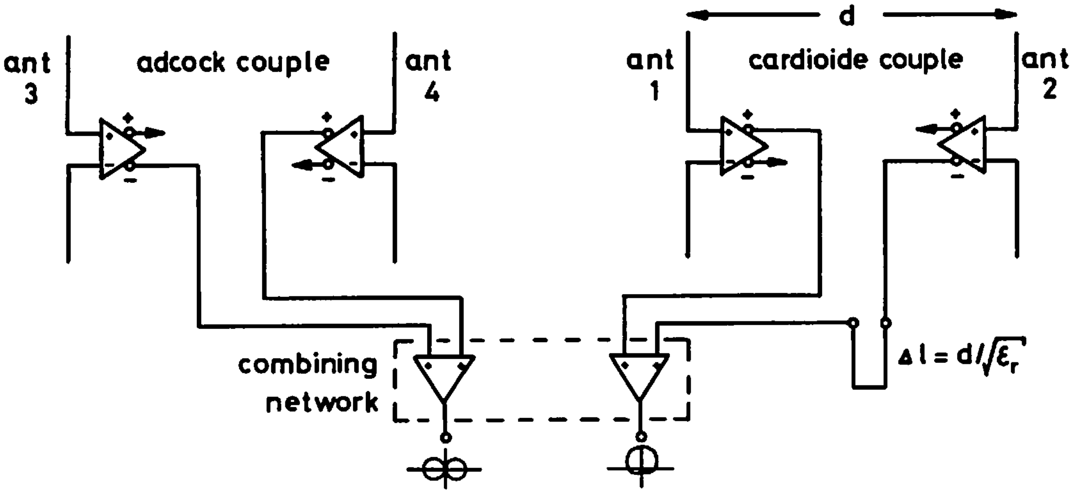


Fig.3: Block diagram of the transistorized DF-receiving antenna

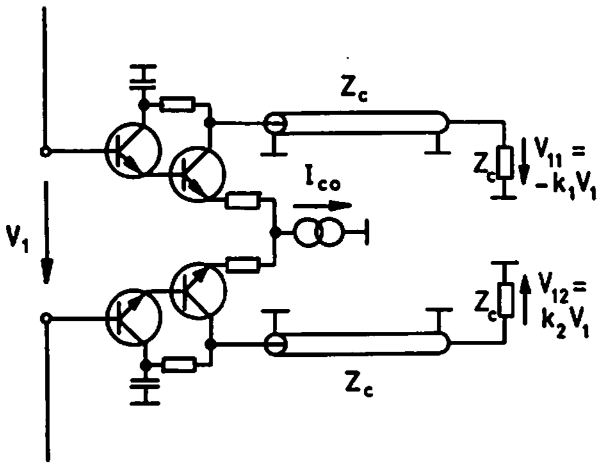


Fig.4: Principle of the antenna amplifier

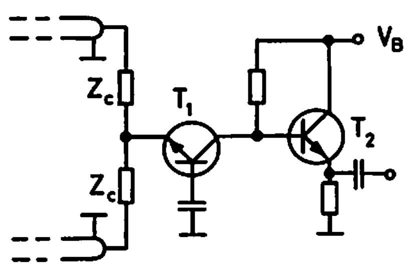
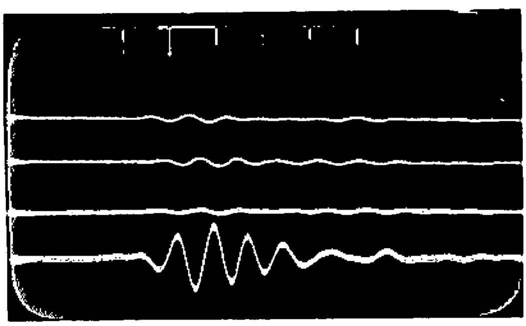


Fig. 5: Voltage adding amplifier



adcock minimum cardioide minimum	antenna axis counter aligned
adcock minimum cardioide maximum	antenna axis aligned

Fig. 6: Pulse received from a reflector at a distance of 860 m.
Intermediary medium: rock salt.