RADAR DETECTOR

Radar signals are used in nautical navigation systems for vessel positioning and distance readings where visibility is restricted. Unfortunately, radar equipment is pretty expensive, so that many owners of small yachts have to make do without an 'electronic eye'. With the aid of the detector presented here these ship owners can, however, implement a basic warning and positioning system by making use of radar signals from other ships.

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RADAR installations make it possible to survey large areas with the aid of electromagnetic waves Not surprisingly, most radar equipment is produced for the avionics, military and nautical industries Since a radar system includes a transmitter, its activity can always be detected Most radars emit a pulsating RF signal at a frequency between 2 GHz and 12 GHz, and receive their own signals, which are reflected by objects within the covered area. The relative strength and the delay of the reflections are measured and used to determine the distance and the size of the object This system allows the area around the radar installation to be mapped and surveyed

For non-professional applications, such as pleasure craft, radar is often too expensive Consequently most pleasure craft can not sail when there is heavy rain or fog.

The radar detector presented here is a low-cost way of using the radar signals of professional craft to prevent collisions, and provide a basic way of ship positioning where visibility is restricted A LED indicator starts to flash, and an audible warning is given, when a radar system is detected within the receive range of the detector. To the navigator, these signals are a sign that another ship is approaching. The detector is directional, that is, it can be aimed at the radar source for an approximate distance and position reading

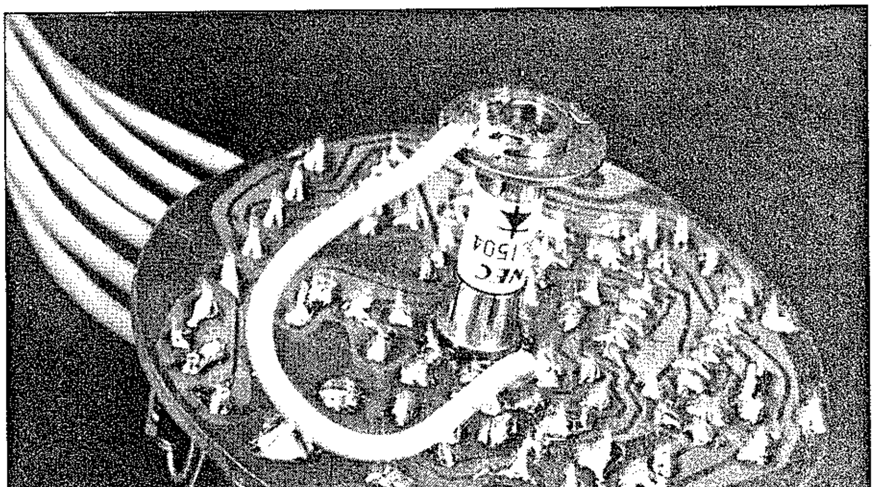

Fig 1. Prototype of the radar detector, seen from the solder side of the PCB.

Frequency bands

Since the peak pulse power emitted by a radar transmitter is of the order of kilowatts, a relatively simple receiver can be used to detect the pulsating RF signals Parts of the frequency bands listed in Table 1 have been reserved for radar systems It should be noted that certain frequencies may be shared with other services, such as radio and TV microwave links, satellites, mobile services and radio amateurs The primary or secondary services in a particular band are determined at a local (often national) level by the relevant telecommunication authorities For example, although radio amateurs are allowed to use certain sections of the 23 cm and 24 cm bands (L-band), they are forced to share them, on a secondary basis, with powerful radar transmitters used for automatic aircraft identification systems installed near military airports Since the radio amateur service has a secondary status in these sections of the band, the interference caused by such radar stations has to be put up with

Radar systems for nautical applications usually work in the X band or the S band More precisely, in the X band the section from 8.5 GHz to 10.68 GHz is assigned to radar, while in the S band two sections are used: 2.3 GHz to 2.5 GHz and 2.7 GHz to 3.7 GHz

Although designed to detect X band signals the present circuit will also work with S band radar systems, so that it is suitable for all conventional nautical radars

The effective range of a nautical radar depends on the transmit power and the height of the antenna Table 2 lists the most important characteristics of currently used radar systems It should be noted that the transmit powers are peak pulse values, not continuous levels The radar transmitter is pulsed to enable distances to be measured (when the transmitter is off, the receiver is on to detect the reflected signal). The transmitter pulse rate determines the maximum distance that can be measured The longer the pulse spacing, the longer the signal will have to travel to cause a reflection that can be measured reliably. Because of the pulsating operation, the continuous power rating of most radars is only a fraction of the peak pulse power

In practice, the range of a radar system depends on a number of factors, including the transmit power, the directivity of the antenna, the propagation characteristics of the

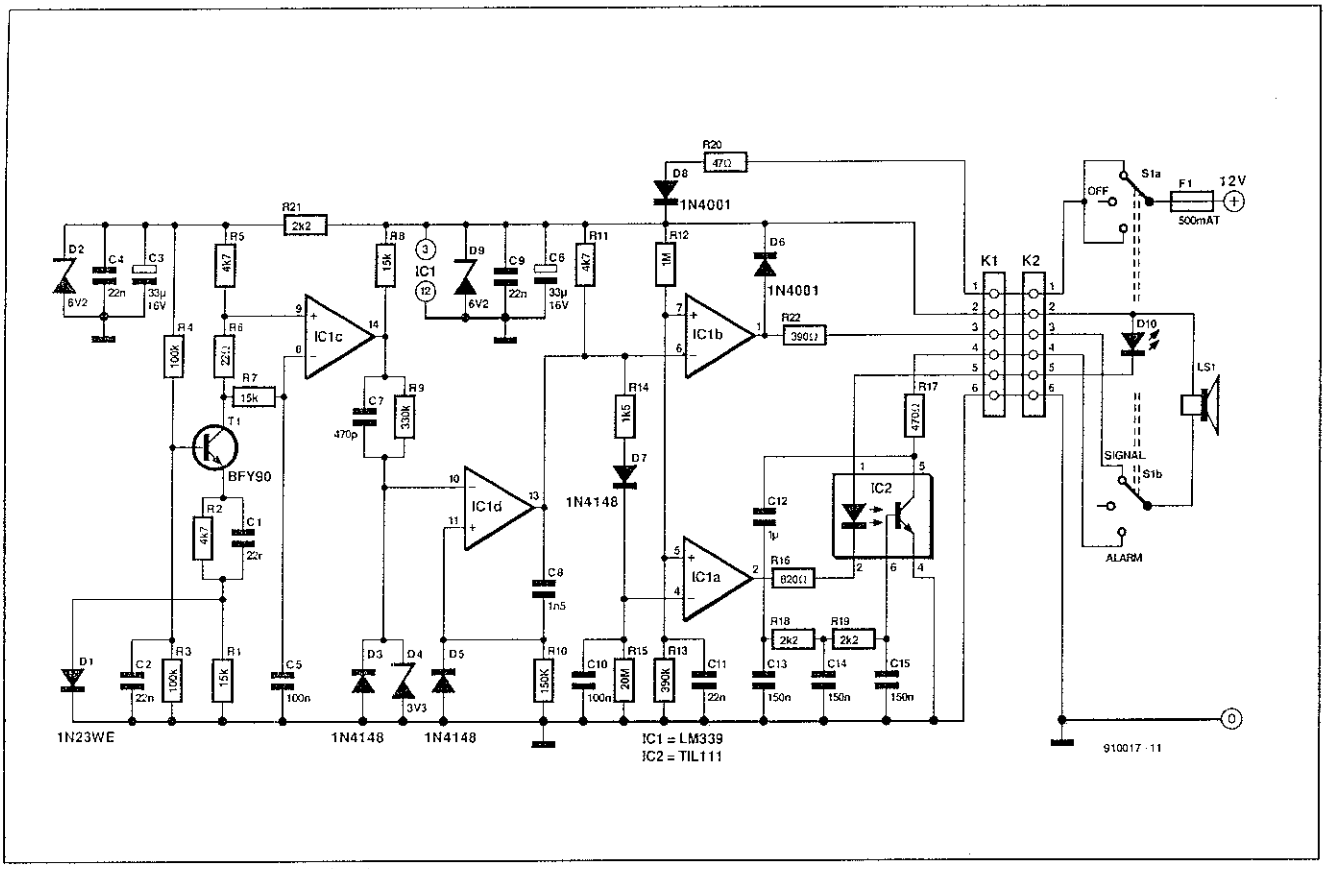

Fig. 2. Circuit diagram of the radar detector.

band used, and atmospheric conditions. The frequencies used for radar are so high that the propagation of the signals is largely similar to that of light. This means that a microwave radar can not, in principle, see objects over the horizon. In practice, however, diffraction, scattering and partial reflection in some atmospheric layers give a radar system a range that extends just over the horizon.

Circuit description

The circuit diagram of the radar detector is given in Fig. 2. Although the circuit is designed to receive very high frequencies, it is relatively simple. The only RF parts in the circuit are a detector diode Type 1N23 and a rudimentary type of antenna which is constructed with the aid of the diode fitting. To achieve maximum sensitivity, a small forward current is sent through the 1N23. This current is supplied by transistor T1. The diode current rises considerably when an RF pulse is received on the antenna. The resultant current pulse causes T1 to conduct harder and supply a voltage pulse at its collector. In this way, the pulsating SHF radar signal is converted into a pulse train that can be processed by low-frequency circuitry. The pulse rate and duration depend on the radar system received by the detector. In general, the pulse rate will lie between 400 Hz and 4 kHz.

The large changes in the collector current of T1 cause the voltage at the +input of opamp IC1c to drop considerably. The voltage at the inverting input remains stable much longer because of capacitor C5. The output of the opamp goes low when a radar signal is received. Components R9 and D4 limit the output signal of IC1c to a value of 3.3 V.

A further opamp, IC1d, is used to convert the short pulses into a signal with a fixed pulse length of 1 ms. The output of this monostable multivibrator is applied to two sub-circuits. Opamp IC1b amplifies the pul-

Table 1

Band designation	Nominal frequency range	Specific radiolocation (radar) bands (ITU Assignments for Region 2)
VHF	30 – 300 MHz	138 – 144 MHz
UHF	300 – 1000 MHz	420 – 450 MHz
L	1 – 2 GHz	1,215 – 1,400 MHz
S	2 – 4 GHz	2,300 – 2,500 MHz
		2,700 – 3,700 MHz
C	4 – 8 GHz	5,250 – 5,925 MHz
X	8 – 12 GHz	8.5 – 10.68 GHz
Ku	12 – 18 GHz	13.4 – 14.0 GHz
K	18 – 27 GHz	24.05 – 24.25 GHz
Ka	27 – 40 GHz	33.4 – 36.0 GHz
V	40 – 75 GHz	59 – 64 GHz
W	75 – 110 GHz	76 – 81 GHz
		92 – 100 GHz
mm	110 – 300 GHz	126 – 142 GHz
		144 – 149 GHz
		231 – 235 GHz
		238 – 248 GHz

Table 2

Vessel type	Beamwidth (degrees)	Antenna height (metres)	Power (kW)	Range (naut. miles)
river transport	1.5°	4	5	2.5
yacht	3°	4	3	1.5
trawler	2°	6	10	3
coaster	1.5°	8	10	5
container/bulk vessel (X-band)	1°	30	50	8
container/bulk vessel (S-band)	3°	30	50	3

ses supplied by IC_{1d} and drives a small loudspeaker. The output signal of IC_{1d} is also fed to a single-phase rectifier that consists of R_{14}, R_{15}, C_{10} and D_7. Capacitor C_{10} is charged via R_{14} and D_7 as long as the output of IC_{1d} supplies positive pulses. The capacitor can only be discharged via R_{15}. Since R_{15} has a much higher value than R_{14}, C_2 can not be discharged completely until the pulse train from IC_{1d} has ceased. When C_2 is kept charged, the inverting input of IC_{1a} is at a higher voltage than the non-inverting input. Consequently, the LED in optocoupler IC_2 lights, and causes an oscillator based on the transistor in IC_2 to operate. The generated AF signal is fed to the loudspeaker via resistor R_{17}. At the same time, LED D_{10} lights.

Switch S_1 allows the loudspeaker to produce either the detected pulses or the continuous warning signal. The same switch is also used to switch the detector on and off.

The battery voltage is filtered with the aid of R_{20} and C_{11}. Diode D_9 limits the circuit supply voltage to about 13 V and prevents the circuit being damaged by overvoltage. The supply voltage of the detection diode is reduced to about 8 V by D_2 and R_{21}, with capacitors C_{11} and C_3 providing additional filtering, and C_4 and C_6 ensuring the required RF decoupling of the power supply.

Construction

As shown in the photograph of the prototype, the detection diode is mounted centrally at the track side of a round printed-circuit board. The crucial part in the circuit, the 1N23, is a point-contact diode with an extremely low stray inductance. The device, which is probably familiar to those of you who have 'microwave' experience, has a white ceramic body and gold-plated terminals. Since the device is easily damaged by overheating, it must never be soldered. Always secure the diode with the appropriate fixing sockets, which can be salvaged from surplus SHF military equipment such as the famous APX-6 transponder (a visit to an electronics surplus shop will probably secure the 1N23 and the associated fixing sockets as spare items). It should be noted that there exist a number of equivalent or near-equivalent types of the 1N23, all of which can be expected to work in the circuit. One near equivalent, the DC1504 from NEC, is shown in the photograph of the prototype, Fig. 1.

The antenna of the radar detector consists of a 15-mm dia. plate soldered to the anode connector as shown in Fig. 2. A short piece of wire connects the antenna to C_1-R_2 on the printed-circuit board. Although a purpose-designed PCB is shown in Figs. 2 and 3, the circuit should also work without problems when constructed on a piece of veroboard or stripboard.

The completed circuit board and the attached detector diode must be fitted in a metal enclosure with a small hole drilled in the front cover. The hole is drilled at a position facing the antenna fixed to the detector diode. The hole gives the radar detector a directivity of about 25°.

Depending on the mode selected with S_1, the loudspeaker produces either the rattle of the received radar or an intermittent alarm sound with pauses of about 1.5 s. As already noted, the frequency of the received radar pulses depends on the system used. In practice, you can expect almost any frequency between 400 Hz and 4 kHz. The sound is probably produced as short bursts because radar antenna rotates. Usually, the antenna has a speed of 22 rotations per minute, which results is bursts with a repeat rate of 3 seconds. You can tell the presence of more than one ship equipped with radar when the detector produces bursts with a repeat rate shorter than 3 seconds. To determine the approximate position of a radar source, hold the detector in your hand and slowly turn it horizontally, sweeping the horizon. ■

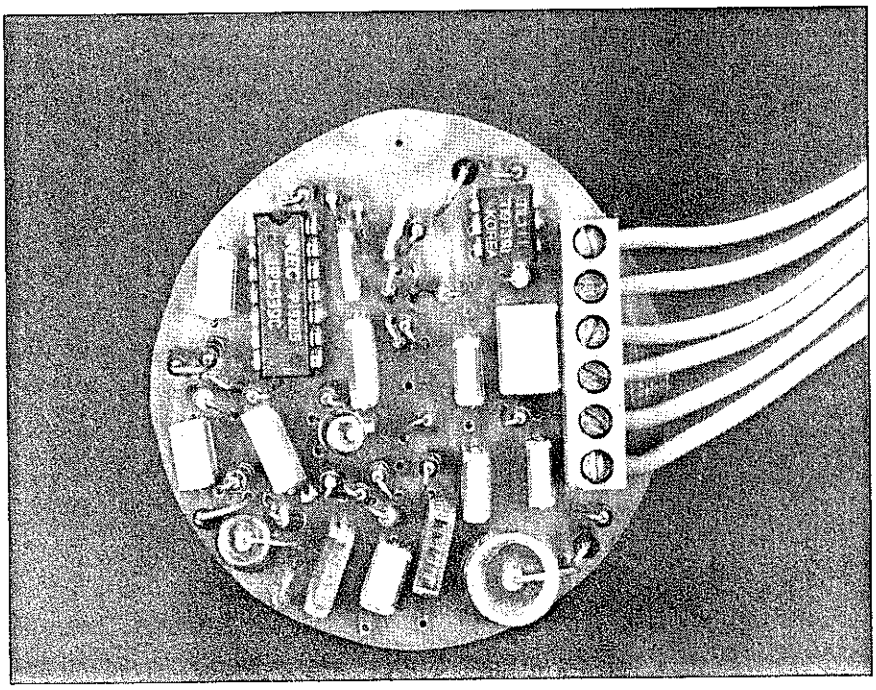

Fig. 3 Component side view of the radar detector PCB. A six-way terminal block is used to connect the supply, switch S1, the LED and the loudspeaker.