14.5 GHz transponder developed for airport surface detection radar

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It's a very dark and rainy night. An emergency vehicle races across the runway at a large metropolitan airport. Just as it reaches the end of the runway, a large jumbo jet appears out of nowhere, just about to land. The pilot sees the vehicle, but at 200 mph and only seconds to spare, there is nothing he can do. The engine pod on the starboard wing hits the truck causing the plane to swerve off the runway and to explode in flames. The result: 50 killed, 103 injured. It could have been worse if the plane was fully loaded.

What went wrong? The plane had clearance to land and was on the right runway. The vehicle via its radio-telephone had told the control tower it was proceeding along the runway. Unfortunately, atmospheric attenuation and clutter caused by the heavy rain prevented the airport surface detection radar from being able to detect the small vehicle. Being totally obscured, both visually and on the radar screen, the air traffic controllers thought the runway was clear, when it wasn't. The results were tragic.

The above scenario is fictitious, but it could happen at a busy airport. In fact, a ground collision occurred not long ago at Chicago's O'Hare Airport between a taxing jet and one taking off.

It is for this reason that target enhancement techniques are being evaluated for tagging small planes, vehicles and even personnel, so they will provide target-like signals when illuminated by surface detection radars.

At Stanford Research Institute, Menlo Park, CA, an inexpensive cooperative beacon transponder, (Fig. 1), has been developed operating at 14.5 GHz that allows an airport surface detection (ASD) radar with a receiver noise figure of 11 dB to receive a clear response up to a range of 3.5 miles in heavy rain (16 mm/hour) and over five miles in clear weather. If the ASD radar receiver noise figure is reduced to 4.5 dB, then a range of five miles can be achieved in 16 mm/hour of rain.

Impatt transponder costs $450 in qty

The transponder consists basically of a pulsed low Q, Impatt diode oscillator, which serves as a transmitter and a tunnel-diode detector in the receiver. Low cost digital ICs are used for processing, gating, isolation between receiver and transmitter and pulse shaping.

"Cooperative beacon transponders aren't anything new, having been used for iff and airborne air traffic control for years," admits Ashok Gorwara, who developed the device at SRI. "These beacons, however, are usually high power, long-range equipment and vary in cost from several hundred to several thousand dollars."

"The simple beacon transponder that we have developed is designed to cost about $450 in quantities of a few thousand. Properly packaged, it will be small enough to be carried on a person, and it is specifically designed to work with an airport surface detection radar. In addition, discrete address capability can be added to the transponder if required for automatic identification and selection.

There are presently three types of radars in use at most of the major airports throughout the world today. In the U. S., the most common is a radar built by AIL of Deer Park, NY, which operates at 24 GHz. A number of these surface detection radars were installed at about 10 major U. S. airports in the early 60s, but they're generally considered obsolete today and modifications are being made to update them. A number of more recent installations employing a 35 GHz radar made by Decca Radar in the U. K., are now at several European airports. Texas Instruments in Dallas, TX, has been working on a 14.5 GHz and 16.5 GHz ASD radar since the late 60s. The transponder developed by SRI is designed to work with the TI system.

Several options considered

"There are several reasons why we selected the TI radar," Gorwara explains. "The main one was that weather clutter backscatter and attenuation simply ruled out developing inexpensive and very high-power transponders at 24 and 35 GHz for application to a range of five miles." Attenuation in heavy rain is only 4.8 dB/nm at 16.5 GHz and slightly lower at 14.5 GHz; while at 24 and 35 GHz, it's 9.6 dB/nm and 24 dB/nm respectively. The 35 GHz radar would, therefore, require the greatest target enhancement even though its antenna offered the highest gain and narrowest beamwidth. Under

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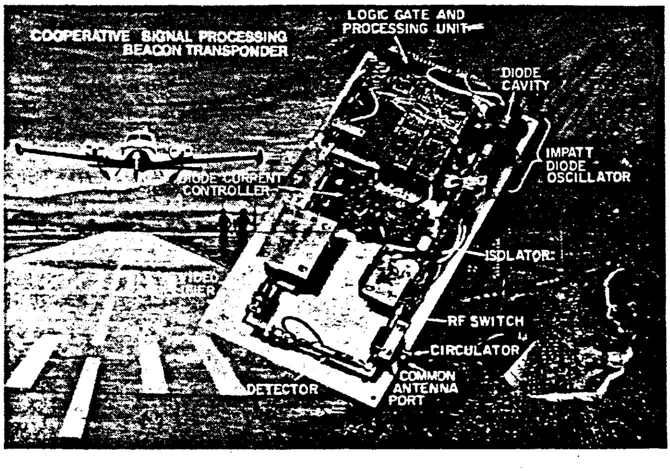
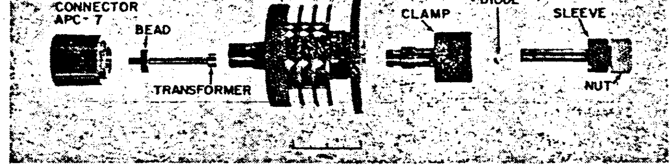
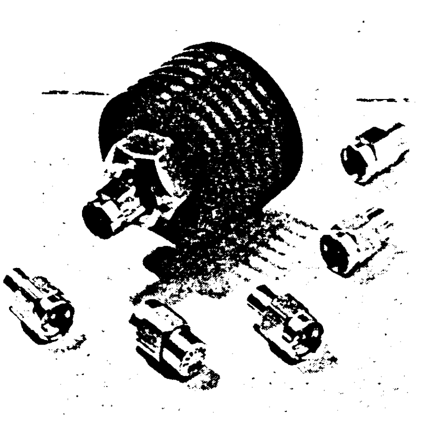
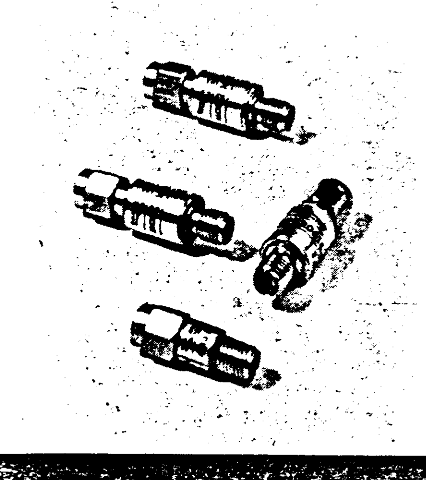


1. Small planes with their low radar cross section are often difficult to detect by an airport surface detection radar. Cooperative beacon transponders make such small targets visible to airport controllers.



2. Prototype beacon transponder uses an Impatt diode transmitter which provides 2.4 watts at 14.5 GHz. The double-drift Impatt diode is pulsed by an rf switch.





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the most severe conditions of 16 mm of rain per hour and at a range of five miles, 182 kW of effective radiated peak would be necessary to produce a signal-to-noise ratio of 13.8 dB in the 35 GHz Decca radar receiver, assuming a 16 dB noise figure. The power will be reduced to 18.2 kW for 6 dB noise figure receiver. At 24 GHz, 240 W peak is required. To achieve the same signal-to-noise ratio under similar environmental conditions at 14.5 GHz would require only 3.3 W peak, assuming a 4.5 dB receiver noise figure.

Because these power levels are not feasible at 35 GHz or 24 GHz, it was decided to develop the transponder at 14.5 GHz. "It was also decided from a cost point-of-view," says Gorwara. Similar designs could be developed at 24 GHz and 35 GHz if the range could be cut to 1 or 2 miles instead of 5.

"We also looked into increasing the range of detectability using passive and active reflectors. However, here we found that the required radar cross-section, about 30 dB sm, at 16.5 GHz was simply too large an area for a corner reflector. Also, too many array elements would be required in a Van Atta array if an active-reflector technique was selected."

Rf switch provides pulses

Figure 1 shows the essential parts of the transponder developed at SRI. It uses a single antenna with transmitter and receiver combined via a circulator. A high-gain video amplifier with limiting capability is used to amplify the detected pulses. The limiting mode minimizes pulse envelope distortion for any false triggering of the logic gate. This limiting scheme allows the beacon transponder to be used at both close and far range from the ASD radar.

The Impatt oscillator, Fig. 2, uses a double-drift Impatt diode, that provides a peak power of 3.3 W and pulses 50 ns wide. A T^2L compatible rf switch is operated in time sequence after the Impatt oscillator is operating in a steady-state condition. This control is maintained by the memory logic. The rise and fall times of the output pulsed rf signal are thus strictly dependent on the rf switch operation. To conserve the dc power consumption, the Impatt oscillator is also pulsed at the same rep rate but with a much larger pulsewidth.

"The only drawback of the rf switch is the extra insertion loss introduced which decreases the overall system efficiency," Gorwara notes. "In production-type models, the switch can be eliminated and an Impatt diode oscillator with current shaping networks can be used."

In the receiver, the tunnel-diode detector is designed to detect a minimum power level of −42.5 dBm with a sensitivity of −28 dBm for signal-to-noise ratio of 13.8 dB, assuming a probability of detection of 0.95. For improved sensitivity, a mixer receiver with a Gunn LO could be used.

Field test—3.5 miles range in rain

In tests, it was found the power output was slightly low, 2.4 W instead of 3.3 W, because of excessive losses in the output isolator and switch, (3.2 dB instead of 2.8 dB as theoretically expected). "The Impatt diode oscillator was also slightly less efficient than expected, 7% instead of 10%," explained Gorwara. "If this transponder is used in the field tests with a simple dipole antenna with 2.2 dB gain, then the effective radiated power will be greater than 3.3 watts."

Based on a transmitted peak power of 2.4 W from the transponder, the maximum range achievable to the 14.5 GHz ASD radar (with a 4.5 dB noise figure) is 3.5 miles in 16 mm/hour of rainfall and greater than 5 miles in clear weather. Based on the actual beacon transponder receiver senstivity of −30 dBm, the maximum range from the 14.5 GHz ASD radar is 1.6 miles in 16 mm/hour of rainfall and 2.5 miles in clear weather. The dynamic range of the rf power input is from −42 dBm, the noise level, to +10 dBm. The lower limit is set by the diode detection noise level, while the upper limit is arbitrary, based on limiting characteristics of the diode detector.

When operating, the cooperative beacon transponder is not expected to receive signals any higher than −5 dBm. ••