A Missile Borne Radar Beacon for Use With Oklahoma A. and M. Triangulation System

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The radar beacon to be described was designed and built by the Research Foundation of the Oklahoma A. and M. College. It is a part of a Radar Triangulation System which was built at the same time. This beacon, shown in Figure 1, is the airborne portion of the system and is designed to occupy a small space and be as light in weight as possible. Unitized mechanical design features are utilized so that it may be adapted to available space in large or small missiles. There are 19 tubes involved in its circuits and in most cases the subminiature types are used. Power is supplied by batteries or in the larger missiles from an a-c operated power supply. Recovery of the beacon after flight is not guaranteed; therefore, the beacon is considered to be a one-shot unit.

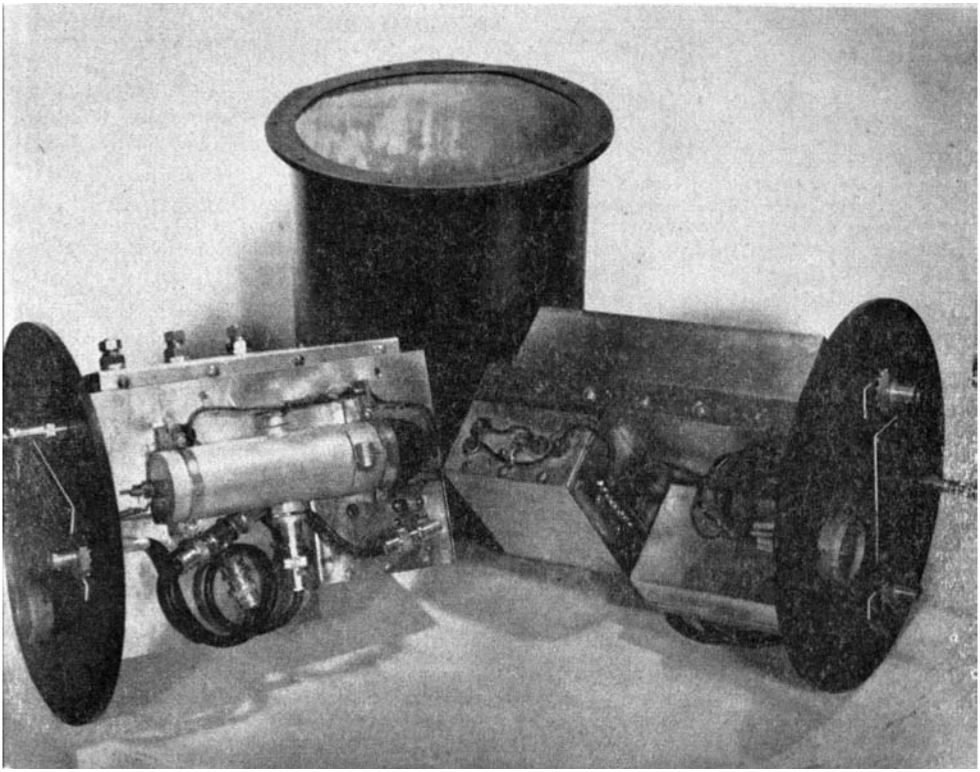

FIGURE 1. Radar Beacon.

The beacon is designed to perform three major functions. The primary purpose is to receive the double pulse interrogation signal from the main ground station and transmit a reply signal to all ground stations. This makes the beacon a part of the range loops for the triangulation system. The second function of the beacon is to actuate a detonation circuit at the command of the operator at the interrogation station. The detonation circuit causes the missile flight to be destroyed or separates the instrument bearing nose section, whichever is desired in the flight. Destruction may be desired if, for some reason, the missile is known to be off course. As a third function, the beacon will actuate the same detonation circuit when the interrogating signal has been absent for a period of two seconds. This function is called fail-safe and is used to destroy the flight of the missile when triangulation positioning information has been lost.

The beacon is composed of five separate units. They are the mixer-oscillator, the intermediate frequency amplifier unit, the decoder unit, the modulator and the transmitter. A block diagram of the beacon with its five units is shown in Figure 2.

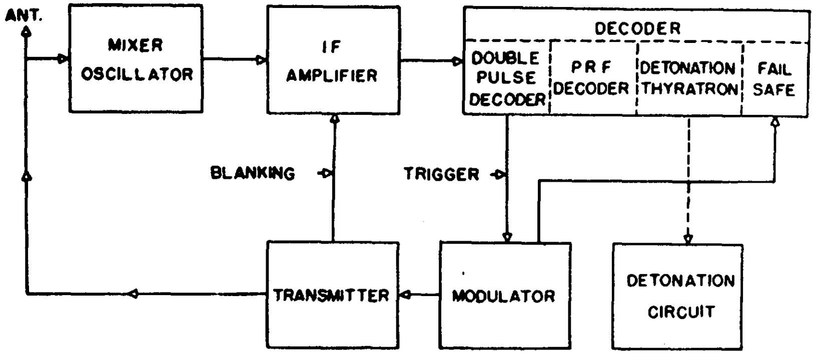

FIGURE 2. Block Diagram of Beacon.

The receiver in the beacon is of the superheterodyne type and involves the use of the mixer-oscillator and the intermediate frequency amplifier. It has many of the characteristics employed in the present day television receivers. It has fairly high amplification and a broad frequency bandwidth response feature such as is required to pass video picture information in television reception. The signal received by the beacon, which is the signal supplied by the interrogation transmitter at the main station, is composed of a pair of 600 mc. r-f pulses of one microsecond duration each, which are spaced 14 microseconds apart. These pairs of pulses recur at the normal rate of almost 400 pairs per second. The local oscillator in the beacon generates a c-w signal of 570 mc. which when mixed in the converter with the incoming 600 mc. signal produces a resultant 30 mc. intermediate frequency signal. The 30 mc. signal is amplified and demodulated in the I.F amplifier unit. The I.F. amplifier consists of four stages of amplification and a diode detector. The over-all gain of the receiver is about 80 db. with a frequency bandwith of 3 mc. Automatic gain control and beacon transmitter signal blanking circuits are incorporated in the I.F. amplifier. The output of the receiver consists of pairs of video pulses with the same coding configuration as the incoming r-f signal.

The double pulse decoder develops a trigger for the beacon modulator in such a manner that the beacon will not reply on any interrogation coding configuration except the double pulse from the interrogator. This is done to eliminate any spurious beacon replies from interfering radar signals or random noise interference. Double pulse decoding is accomplished by delaying the first of the pair of coded pulses and holding it until the second of the pair arrives and using the combination of the two pulses to develop a trigger for the beacon modulator. The first pulse is delayed by the use of an artificial transmission line.

The modulator unit has an amplifier stage to increase the voltage amplitude of the trigger and a gas discharge thyratron to develop a transmitter modulating pulse. This pulse has an amplitude of 1,500 volts and a duration of about one microsecond. It is almost coincident in time with the second of the received coded pulses.

The transmitter is a folded back coaxial type known variously as a tuned-plate tuned-cathode, grounded grid or grid separation oscillator circuit. It uses a lighthouse type tube with coplanar elements. The transmitter is plate modulated by the modulating pulse and develops a peak r-f power output of about 200 watts at 580 mc. The transmitter output is coupled to the receiving antenna through a duplexing section of r-f coaxial cable. This eliminates the necessity of using separate antennas for transmitting and receiving.

The foregoing discussion describes the beacon as a link in the triangulation system. The detonation functions will be described below.

The simplest method of actuating the detonation circuits associated with the beacon is to change the recurrence frequency of the interrogation transmitter at the main station. For this system the normal recurrence frequency of almost 400 pairs per second is changed to 854 pairs per second. This involves the use of a frequency selective circuit in the beacon to actuate the detonation circuits at command. The same trigger pulse that is usd to key the beacon modulator is applied to a "pulse to frequency selective sine wave converter". Since the average energy of the trigger pulses is too low to use in a frequency selective circuit, it is used to key an Eccles Jordon multivibrator. The multivibrator has two stable states and its output is a square wave with a frequency of one-half the trigger recurrence frequency. The square wave is applied to the input of a regenerative amplifier. This amplifier has maximum regeneration at one-half the command recurrence frequency of 854; therefore, its output is greatest and is an almost perfect sine wave when the recurrence frequency is 854 per second. This increased output is used to ignite a thyratron gas tube and its heavy current may be used in turn to actuate a relay or other methods of detonation.

During normal operation the detonation thyratron is held non-conducting by a bias voltage which is developed in the modulator unit. If the beacon fails to function as a link in the triangulation system, this voltage disappears and after a capacitor charging delay of two seconds the thyratron will conduct and actuate the same detonation circuit. Beacon link failure might be internal to the beacon, or it could be due to lack of the proper interrogation signal. In either case, it may sometimes be desirable to destroy the flight of the missile because of lack of position information. The two second delay in detonation allows time for the beacon to recover in its operation in case the failure is an intermittent one.

This radar beacon fulfills the requirements of its functions as they were originally set forth. It is, however, feasible that it could be designed to perform other functions which have not been mentioned. In other triangulation systems, beacons have been designed to perform functions similar to those of this beacon with the added feature of telemetering various types of upper atmospheric information to the ground. This has been accomplished by allowing the beacon to transmit more than one reply pulse during each cycle of operation. The auxiliary reply pulses are delayed in time from the range pulse by an amount proportional to the information being telemetered. This information may be such measurements as temperature, pressure, or light intensity. Command information other than destruction might also be transmitted to the beacon. This could be accomplished by using several recurrence frequency channels or by using various configurations of pulse spacings.

Modifications of this beacon have been made but all have been toward a more simple design. One modification for size reduction has utilized single pulse interrogation with the decoder unit and detonation circuits completely omitted. Another modification utilized single pulse interrogation with a tuned inductance-capacitance circuit to actuate the detonation circuit when a change in recurrence frequency is made.