Proximity Fuzes
Theory and Techniques

VK Arora

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PROXIMITY FUZES
THEORY AND TECHNIQUES

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Preface

This monograph deals with theory and design aspects of RF-FMCW and Laser proximity fuzes. The book begins with a short history of development of proximity fuzes. The successful development of the fuze by the US during the Second World War was an outstanding technical achievement. Though the Radar, a more complex system had been developed and used during the war, there were unique features of the proximity fuzes which made its development extremely difficult. The ability of the fuzes using vacuum tubes to withstand 'g' shocks of ten of thousands when fired from the gun, was considered a formidable task. The development of the fuzes was so significant that many experts consider this to be next only to the development of atomic bomb. The history of development in India from 1966 to 1975 is also briefly covered.

Lack of technical literature on the proximity fuzes was the key motivation to write this monograph. The book will be useful at many levels: Professionals who specialise in allied/areas such as a missiles, young engineers who are entering the fuze development programmes, military personnel who use these fuzes and electrical/ electronics engineers for general reading.

The book is divided into three main subject areas. The first section considers the basics of proximity fuzes. The second section deals with FMCW fuzes. The last section covers the latest Laser Proximity Fuzes.

Chapter 2 gives an overview of Proximity Fuzes. This chapter contains material everyone associated with proximity fuzes should know, in particular, the users and the decision makers. This chapter covers the evolution of CW proximity fuzes from fuzes developed during the second World War to the FMCW fuzes which became the workhorse fuze after the 1980s and continues to be most effective proximity-sensor till today. This chapter gives an overview of all of the subsystems of FMCW and the recent Laser proximity fuzes. The chapter also addresses the problem of 'g' - several tens of thousands which the fuzes for high speed artillery and anti aircraft shells have to withstand.

Chapter 3 on the fuze range equations is a standard material available in Radar texts but is included for the basic orientation and for the sake of completeness.

Chapter 4 deals with reserve battery and power sources required by all types of fuzes - FMCW, their variants and Laser proximity fuzes.

Chapters 5, 6 and 7 deal with of FMCW fuzes and their sub-systems.

Chapter 5 deals with voltage controlled oscillators. In particular the importance of phase and amplitude noise of oscillator is addressed because low phase and amplitude noise are a fundamental requirement of fuzes. The active devices which achieve the objective of low noise are considered and compared.

Chapter 6 on the mixers deals with highly linear mixers - Gilbert cell mixers and FET resistive mixers. High degree of linearity is a basic prerequisite of mixers since the modern fuzes operate in an intense environment of Electronic Counter Measure (ECM). ECM signals can penetrate into the receiver through the mixer non-linearity.

Chapter 7 deals with microstrip antennas for fuzes. These antennas can be used with a wide range of fuzes which requires a radiation pattern along the projectile axis such as fuzes for bombs, mortars and high angle artillery shells. Fuze antennas need a fairly high impedance bandwidth to reduce reflections from a common antenna system which most conventional ammunition are constrained to use. This chapter considers various options to achieve high bandwidth.

Chapter 8 on the FMCW fuzes contains the basic general principles of FMCW and explains the unique properties of FMCW fuzes .The problem of single antenna FMCW fuzes, that of the leakage of transmitted power with its attendant noise to the receiver are considered. The chapter demonstrates that a low noise VCOs and a highly linear mixer make the FMCW fuzes as one of the best proximity sensors.

The third section of the book discusses the pulsed laser proximity fuze with its two most important subsystems, viz., the laser sources, the photodetectors and nanosecond pulse generators to drive the laser source.

Chapter 9 covers the specific sources and their properties that make them eminently suitable for pulsed laser fuzes. In particular, the microslab solid state lasers which are capable of providing very high peak power short pulses required for anti-aircraft fuzes are described. Importance of noise in photodetectors due to solar background radiation and optimisation of APD gain to achieve high signal-to-noise ratio in laser receivers is given special attention.

Chapter 10 deals with nanosecond pulse generators. Fuzes which function at a range of few metres to tens of metres require pulses with a width of 2-10 nanoseconds. Techniques of achieving short nanosecond pulses based on Avalanche transistors and high speed MOSFETS are dealt with .

Chapter 11 on Laser proximity fuzes deals with principals of laser range finding as applied to very short ranges. Broadly various systems aspects, like the power requirement of fuze transmitter and the type of receivers required for achieving high dynamic range are described. System considerations like background solar radiation and attenuation in fog and clouds, detrimental to fuze performance are described.

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Chapter 1

History of Proximity Fuzes

1.1 SIGNIFICANCE AND BACKGROUND OF THE RADIO PROXIMITY FUZE IN WORLD WAR II[1]

The radio proximity, or VT fuze for artillery shells represents a major contribution to the success of the war in Europe as well as in the Pacific. Its development, production, and military use is an outstanding example of collaboration by R&D groups, industrial organisations and the military services.

A fuze is that part of an artillery projectile which detonates the explosive charge and ideally would detonate the shell in the most optimum position to inflict maximum damage to the target. Early in the war, it became evident that speed, manoeuvrability, and heights attainable by modern military aircraft presented a method of attack against which fuzes currently available for anti-aircraft guns were relatively ineffective. Even with the improvements in directing anti-aircraft gunfire made possible by radar, low probability of hitting elusive attacking aircraft made the problem of defence against aircraft extremely important and urgent for a nation involved in the war.

The idea of proximity fuzes is not unique and was suggested independently by many in the United States and other countries prior to 1940. However, the obstacles in the way of actually developing a fuze of this type seemed insurmountable. Many technical experts, who had witnessed an anti-aircraft demonstration, had toyed with the idea of a proximity fuze. The small target area presented by an aircraft, practically forced a serious and urgent need for a fuze which would detonate in the vicinity of the aircraft.

The inherent disadvantages of the time fuze and the contact fuze stimulated the need for proximity fuze. The time fuze, which detonates a projectile at a specified time after it leaves the gun, has been widely used against aircraft and personnel. However, use of time fuzes requires, not only that time of flight from the gun to the aircraft be calculated precisely and immediately before firing, but fuze time be set accordingly. A slightest error in fuze time estimate or setting may cause the projectile to explode at a harmless distance from the target.

The probability of success of the contact fuzed projectile in an anti-aircraft role is extremely limited, since it must actually hit its target before it detonates. As range lengthens, this becomes almost impossible.

It has long been recognised that the efficacy of explosive projectiles would be greatly enhanced if these could be equipped with fuzes which would be actuated by the proximity to a target. For example, an anti-aircraft projectile which would automatically detonate when coming within lethal range of an aircraft would simplify fire control techniques and would be highly effective.

Although inventors had suggested almost every possible type of proximity fuze, they failed to indicate how the formidable development and engineering difficulties could be satisfactorily overcome. Such fuzes to be useful for artillery purposes, would have to be capable of withstanding the shock of tens of thousands 'g's when fired from a gun, in addition to undergoing a high rate of spin imparted to a shell. Many patents on proximity devices were issued in various countries, but they failed to suggest any concrete technique to solve formidable problem.

British scientists were working on proximity fuze devices for rockets and bombs at least as early as 1939. Captured documents indicate that German work on proximity fuze development had begun even earlier, as early as 1930's, and was still in process when hostilities ended in the Europe. The possibility that proximity fuzes of various types might be feasible, had been recognised for a long time. The American achievement, accomplished by no other country, was the actual development of a proximity fuze that would function and that could be manufactured by mass-production techniques. The development work, started during 1940, was carried out in the Department of Terrestrial Magnetism (DTM), Applied Physics Laboratory, National Bureau of Standards, and Crosley Corporation.

1.2 DEVELOPMENT WORK IN THE DEPARTMENT OF TERRESTRIAL MAGNETISM[1]

During August 1940, a group called Section-T of the National Development Research Council (NDRC) was established under Dr Merle Tauve of the Carnegie Institution. The Group led by Dr Tauve, and assisted by Richard Roberts was to conduct research in the Laboratory of Territorial Magnetism of Carnegie Institute, Washington. The Group was convinced that whatever method was selected, it would involve substantial electronics. They had begun firing vacuum tubes from a small gun and had found that these frequently survived the ordeal.

In September 1940, the British Technical Mission headed by Sir Henry Tizard, NDRC received a report from British that although Britishers were consuming thousands of vacuum tubes manufactured by two largest manufacturers of vacuum tubes in US towards the development of fuze, but they had not yet made a workable fuze. Both the US and the British considered similar approaches as follows:

(a) A radio fuze that would sense the proximity of the aircraft
(b) A radio fuze tracked by anti-aircraft gun's radar that would be triggered from the ground when its range was the same as that of the target.
(c) An acoustical fuze actuated by dominant resonance of the aircraft engine and propellers.
(d) An optical fuze actuated by the photodetector current at the frequency of projectile's rotation, in the presence of ambient light.

The Tizard Mission showed a fuze circuit that had been developed by UK scientists, to the DTM Group and Dr Roberts made a copy of the circuit the day after receiving it and its performance impressed the Group so much that the British approach gained high priority, especially as it showed promise of miniaturization.

The basis of the fuze was an 80 MHz free running Hartley oscillator with its output connected between the body of the projectile and a metal nose cone. The plate current of the oscillator developed a voltage across the load resistance in the plate circuit. This voltage was fed through a low-pass filter to a two-stage audio amplifier. The plate current changed when an object entered the near-field of projectile's radiation pattern, and this change, which occurred at the Doppler frequency determined by the relative velocity of the projectile and target, was amplified and applied to a thyratron whose conduction exploded the shell. The designer of this circuit was the New Zealand born, W.A.S. Butement, one of the Britain's best radar engineer.

Dr Roberts successfully completed two simple experiments within 48 hrs of hearing about the Navy's interest in fuze. He conducted a drop test to simulate high 'g' by mounting the vacuum tube on lead brick and dropping it on steel plate from the building roof-top. Tests were quickly extended to a centrifuge and were followed up by firing the fuze on test-loaded projectile from 37 mm gun on a farm near Vienna, Virginia. The high 'g' survival tests coupled with successful laboratory tests on Butement circuit, where a small movement anywhere in the room where the fuze oscillator circuit was loaded with a quarter wave dipole, causing a relay to actuate, gave tremendous confidence to the DTM Group.

In April 1941, 35 weeks after the beginning of the project, a fuze oscillator was fired from the gun. By June 1941, circuit work had been carried to the point where a circuit of sufficient sensitivity and small enough size to be contained in a fuze body, could be made. The circuit consisted of an oscillator, a two-stage low frequency amplifier, a thyratron, and an electric detonator that would initiate the explosive detonation. A dry battery built by the National Carbon Company was used as a source of power. Switches, known as setback switches, were used in the fuze to close the battery circuits upon firing of the projectile. An electrical arming delay was incorporated in the circuit to prevent arming of the fuze until the tube filaments had heated and the unit had stabilised after the initial impact of firing. The oscillator radiated a radio frequency signal in the VHF range. Some of the energy from this radiated field would be reflected back from any target in the vicinity of the projectile in such a fashion as to vary the load on the oscillator at Doppler frequency, causing an low frequency signal which was then amplified by the amplifier and used to trigger the thyratron. The electric detonator in the thyratron output circuit initiated detonation of the auxiliary detonator which exploded the explosive charge.

In September 1941, tests of complete fuzes were started at Naval Proving Grounds, Dahlgren, in the 5 inch 38 calibre projectile. Early Dahlgren tests were not very successful, primarily because of premature failures/short bursts. At this time, a double filament triode tube was being used as an oscillator, and it was discovered that vibrations between these two filaments produced low frequency noise due to microphonics within the audio frequency pass band of the amplifier and were probably the cause of the premature bursts.

In the fall of 1941, the Sylvania Company was brought into the tube program and it contributed greatly towards the development of improved tubes. By January 1942, a test conducted at Dahlgren gave slightly better than 50 per cent successful firing, and which was considered to be adequate to bring a manufacturer in the program. At this time, a development contract was given to the Crosley Corporation to produce the fuze.

1.3 RESEARCH AND DEVELOPMENT WORK AT APPLIED PHYSICS LABORATORY[1]

The growth of the project was so enormous that it required increased administrative support. In March 1942, Tauve Group was placed directly under the control of Office of Scientific Research and Development (OSRD) and a new organisation was formed, the Applied Physics Laboratory with John Hopkins Laboratory sponsoring the work. Tauve became the first Director. After the initial success of vacuum tubes to withstand hostile environment of artillery shell, contracts were placed on Sylvania for the design of very small tubes with strengthened electrode structure. Dry cells used in initial firing deteriorated rapidly in storage. Reserve battery, in which the electrolyte in sealed ampoules was released when the glass ampule was shattered on firing and spun into the electrodes, was developed.

On 12 August 1942, test firing from USS Cleveland at radio-controlled target brought down the only two targets available. On January 1943, USS Helena brought down a Japanese bomber on the fifth round using industrially produced fuze, 28 months after initiation of the project. The unprecedented success came from strict quality control, test firing of several fuzes from production batches, and rejection of lots with blinds beyond five per cent. The fuzes maintained strict reliability standards and were made bore-safe incorporating multiple safety measures.

Field artillery had long used time fuzes for producing air burst over ground targets requiring visual observation of the range, accurate gun placement, and flat trajectory. The accuracy requirement of the fuzes were even more severe for Howitzer where shells descended at high angles to the ground. The optimum height of burst was also dependent on the shell calibre. The anti-aircraft proximity fuze was thus ideal for field artillery shells. Proximity fuze were modified and adapted for field artillery shells.

1.4 DEVELOPMENT WORK AT NATIONAL BUREAU OF STANDARDS[2,3]

Early in the project, it was decided that there were significant design differences with spinning and non-spinning projectiles. The development work of fuzes for non-spinning projectiles – bombs, rockets, and mortars – was carried out by Division-4 of the NDRC, OSRD under the chairmanship of Dr Alexander H Ellett. The heart of Division-4, the control laboratory, was a group at National Bureau of Standards under the leadership of Dr Harry Diamond, a group later known as Ordinance Development Division. In November 1940, Dr Ellett from the University of Iowa had come to Washington to work with Tauve at DTM and a few weeks later, to initiate work at NBS on proximity fuzes for bombs and rockets. In December 1940, Ellett secured the services of Diamond and Hinman for Radio Section at NBS. Diamond/Hinman team quickly realised that the fuze using Doppler effect was the most promising concept. A series of crude models proved the principle, culminating in successful bomb drops in April and May 1941.

In May 1942, the Army stated its first definite and urgent requirement for a proximity fuze for the new 4.5 inch rocket to be used against German aircraft. Diamond team completed the design in two days. NBS and Westinghouse produced initial model lot and tested 55 of these fuzes at Fort Fisher, North Carolina, in June 1942. In December 1942, Diamond/Hinman team was reorganised and enlarged as the Ordinance Division with about 200 people developing proximity fuzes for rockets and bombs. At the end of war, over 400 people were working on the project. About 400,000 of each type were manufactured during 1942 but none were used as intended because the threat from German bombers had subsided. NBS Team solved several problems encountered in bomb fuzes, notably low-temperature problem at high altitudes and battery problem by developing a spinning turbine generating power for the fuze.

1.5 TESTS [2]

On 29 January 1942, a group of fuzes with miniaturised components and dry cell batteries, built on a pilot production line, were installed in standard 5 inch anti-aircraft projectiles and fired from a 5 inch 38 calibre anti-aircraft gun. At the end of a 8 km trajectory better than 50 per cent had successfully activated themselves by proximity to water. The Bureau directed the Crosley Corporation to commence pilot production of the fuzes without delay. The name that was assigned was the ‘VT fuze’, with the VT standing for variable time.

Development of the VT fuze continued in parallel with the pilot production at the Crosley Corporation plant. In April 1942, firing tests – in which the new reserve battery developed by National Carbon Company, was utilised – were conducted successfully. A small plane suspended from a barrage balloon was used as the target. Safety and self-destruction devices were needed to be added to the fuze before it was ready to be used in war.

In another test, similar to the one conducted on 29 January, it was found that reliability of the fuze technology resulted in 70 per cent of the shells that detonated. The next logical step was to conduct a shipboard firing test.

On 12 August 1942, the first time pre-combat service tests were made by the newly commissioned USS Cleveland. The tests were scheduled to be conducted under simulated battlefield conditions. All the three available drones were destroyed early on the first day of tests while going through all possible evasive manoeuvres, by the bursts of only four proximity fuzed projectiles. This was an amazing success.

In the middle of November 1942, 5,000 rounds of proximity-fuzed projectiles were carried to Noumea for distribution to the ships of a task force in the southwest pacific. The first ship to introduce them to the enemy was the USS Helena. On 5 January 1943, four Japanese bombers attacked the task force and the Helena downed one with the second salvo of proximity-fuzed ammunition.

1.6 PRODUCTION SCALE-UP

Following the Crosley Corporation contract, production was increased to great numbers. Beginning in September 1942, newly established facilities commenced production of the ruggedised miniature tube in large quantities. In October 1942, an average of 500 tubes were being manufactured daily. After the fuze had been proven in combat, the expansion of manufacturing facilities rapidly increased. By the end of 1943, almost two million tubes had been delivered. By the end of 1944, 87 contractors, operating 110 plants, were manufacturing parts of the fuze which at that time were being delivered at the rate of 40,000 per day. Fuze assembly was concentrated in the plants of the Crosley Corporation, the Radio Corporation of America, Eastman Kodak Company, and the McQuay-Norris Company. Mass production of the ruggedised miniature vacuum tubes had to be limited to Sylvania Electric Products, Inc., since it proved to be the only firm capable of combining quality and quantity.

1.7 A STRIKING COMBAT SUCCESS [3]

During 1943, approximately 9,100 rounds of proximity fuzed and 27,000 rounds of time-fuzed 5 inch anti-aircraft projectiles were fired. Fifty one per cent of the hits on enemy planes were credited to VT-fuzed projectiles. The proximity fuze-equipped shell's success in repelling air attacks against fleet units reached its peak when a task group in the Pacific reported the destruction of 91 of 130 attacking Japanese planes. The VT-fuzed shells were also used with great success in the Mediterranean and Atlantic theatres.

In late December 1944, von Rundstedt launched a counterattack, which developed into the Battle of the Bulge. The use of the fuzes entered a new field, that of artillery fire against ground forces. The results of this usage was devastating to German troops and was able to generate fear in their hearts. No longer were their foxholes safe against shrapnel burst, for with the use of the 'funny fuze', as it was termed by General Patton, the shrapnel bursts occurred before the projectiles hit the earth, and high-velocity fragments rained down on the German attackers.

1.8 ELECTRONIC COUNTERMEASURES [3]

Its an interesting historical fact that electronic countermeasures were thought of and successfully developed during the World War-II. The need to develop countermeasures against proximity fuzes stemmed from the Germans, who during the Battle of the Bulge, captured an army munitions dump that contained a large number of the new radio proximity fuzed shells. Concerned that the Germans might attempt to copy the proximity fuze, the Research Division of the Aircraft Radio Laboratory at Wright Field, along with the help of the RLL, was called in to begin the development of jamming equipment. The proximity fuze was a closely-guarded secret by the US. Even though, Wright Field Group had been working on the countermeasures for a long time, they had never heard of the proximity fuzes. Now, they had been asked to develop a countermeasure against the fuze on crash basis. Interestingly, they had been told that a group to whom the countermeasure problems has been addressed earlier, had concluded that the fuzes could not be jammed. The Wright Field Group developed a jammer that would detonate the proximity fuzes prematurely within a record two weeks time.

The jammer modification of the existing APT-4, high powered jammer consisted of a motor-driven transceiver which spanned the frequency from 180-220 MHz. A motor-driven tuner was added to sweep the jamming transmitter's signal up and down the band covered by the fuze. Modified APT-4 was installed in a B-17 bomber and tests were arranged at Eglin to test the countermeasure effectiveness. The tests were carried out against proximity-fuzed shells from a 90 mm anti-aircraft gun. Interestingly, the constraint was to use the high explosive-filled shells. So the Group was constrained to use live-explosive VT-fuzed shells. To avoid damage to B-17, the guns were offset by small angle of about 1°. It was a sort of test that could not have been carried out in peace time. However, the risk was worth taking. The tests lasted about three months during which about 600 VT fuze shells were fired in the direction of B-17. The fuze radiated continuous wave (CW) signals. The combination of spinning shell with a small yaw in flight produced the small amplitude modulation on the CW-signal. The experiment was a success, the pilots and navigators could watch the shells bursting well below the aircraft. The conclusion was that a modified APT-4 jammer could greatly reduce the effect of the proximity-fuzed anti-aircraft shell.

1.9 DEVELOPMENT OF PROXIMITY FUZES

The development of proximity fuzes was a formidable effort and it needed all the ingenuity of the scientists, engineers, both in the development laboratories and at the production agencies that culminated in the success of the proximity fuze during the World War-II. By the end of the war, successful fuzes had been developed for anti-aircraft shells, field artillery shells, rockets, bombs, and mortars. A total 22 million fuzes were manufactured during the war. By 1945, the production of vacuum tubes for proximity fuzes was 40,000 per day. Of the 22 million fuzes produced, about a million and half were used during the war.

General Benjamin Lear, USA, described the VT-Fuze as "...the most important new development in the ammunition field since the introduction of high-explosive projectiles". General George Patton, USA, also paid tribute to the fuze developers stating, "I think when all armies get this shell, we will have to devise some new method of warfare".

1.10 POST-WAR DEVELOPMENTS

By the end of World War-II, ordnance with vacuum tube fuzes had reached such a level of sophistication that, between the end of World War-II (1945) and the end of the Korean War (1954), there was limited research and development in new conventional ordnance. This resulted in very little development of new types of fuzes for the ordnance used during this time period. The discovery of the transistor, by Walter H. Brattain and John Bardeen of Bell Laboratories, was made on December 23, 1947.

In 1954, the first fully transistorized radio and computer were built. In 1955, transistors were available for the first time in production quantities. In 1956 investigations began into the use of transistors in fuze circuits. In 1959, the first integrated circuit microchip was fabricated. The development of transistors and microchip technology initiated the replacement of the vacuum tube in proximity fuzes. The first electronic hybrid (transistors and vacuum tubes) fuze, the M532, was developed in the early 1960s for a mortar round. The first fully transistorized fuze, the M429 was developed during 1965-1970 for a 2.75 inch rocket for use in the Vietnam War. M728 was the first fully transistorized artillery fuze and was developed during the period between late 1960s to early 1970s.

1.11 BRIEF HISTORY OF DEVELOPMENT OF PROXIMITY FUZES IN INDIA (1966-1975)

The variable-time (VT) fuze was an important contribution of World War II and it was the first ever attempt to introduce electronics in armaments. While the Indian Navy was using fuzes imported from the UK, the Indian Army did not possess these. Since its aerial burst was effective against ground troops, the development of the fuze was undertaken by ARDE. It was the prime contractor and was responsible for the development of the explosive train. The electronics part was concurrently developed by two R&D agencies, namely the Bhabha Atomic Research Centre (BARC) of the Department of Atomic Energy and by the Solid State Physics Laboratory (SSPL) of DRDO. The BARC was involved in the development of the VT fuze for the 25 Pounder gun while the SSPL's involvement was for the development of the VT fuze for the 75/24 Pack Howitzer. The VT fuzes for the 105 mm IFG and the 75/24 Pack Howitzer were successfully completed and they rolled out of the production line in 1973. For this project, ARDE had two customers, namely the Army and the Indian Navy, two associate R&D agencies in development namely BARC and SSPL, and three production agencies, namely Electronics Corporation of India (fuze for 105 mm IFG) and HAL, both in Hyderabad and an ordnance factory. It was no easy task for ARDE to finalise in association with the agencies involved in development and production and with the User Services, the modalities for testing and proofing the rounds and quality acceptance procedures. The development work on fuzes continued with BARC and SSPL and was crowned with success, with BARC involved in the VT fuze for the 76.2 mm gun for the Navy and SSPL for the VT fuzes for the 130 mm Russian gun for the Army and the 4.5 inch gun for the Navy.

The development of proximity fuzes for 75/24 Howitzer was assigned to SSPL in the year 1966. Dr NB Bhatt was the Director of SSPL when the formal project was entrusted with its design and development. Prof. DS Kothari who was the first Scientific Advisor of the Minister of Defence and headed the Defence Science Organisation formed in 1958. Right from the inception of the project, Dr DS Kothari took keen interest in the development of proximity fuze and monitored its development even after his successor Prof Bhagavantam had taken over as Scientific Advisor in 1961. Dr BD Nagchaudhari who took over as the Scientific Advisor on 1st July 1970 took tremendous interest in the development of proximity fuzes and was great source of inspiration to the author and the team which successfully developed the proximity fuzes for 75/24 Howitzer shell. Major General JR Samson who was the Chief Controller of the Defence R&D Organization was a key driving force. His keen interest in the development of fuzes provided tremendous impetus to the progress of the project.

Some exploratory work on VT Fuzes was being carried out by a small team in a group in Defence Science Laboratory situated in the Metcalfe House complex called the Radar Research Wing under Dr NB Bhatt who later became the Director of SSPL situated at Metcalfe House. This exploratory work continued at SSPL after shifting to Lucknow Road but unfortunately no success on VT fuzes had been achieved.

Soon after the formal sanction of the project to develop a proximity fuze was sanctioned to SSPL in early 1966, Dr NB Bhatt requested the R&D Headquarters that the author be called from DRDL, Hyderabad to lead the fuze project. The author had worked in the Special Weapons Development Team (SWDT) co-located with the R&D research wing in Metcalfe House with Dr BN Singh as its Director. The author joined SSPL in March 1966 and with a team of three other young scientists, PC Nagpal, MN Sen, GJ Chaturvedi and two technicians commenced the work on electronics of the fuze. The team developed a prototype of CW proximity fuze in three months. The fuze electronics developed consisted of a Colpitts oscillator at 220 MHz using an epoxy encapsulated RF transistor, Doppler amplifier, a Schmitt threshold circuit and a transistor switch to ignite the detonator. The fuze oscillator detector was tested for its sensitivity by using a horizontally moving aluminium reflector in the vicinity of fuze. The complete electronics was encapsulated. The oscillator was encapsulated in low density polyethylene. The remaining circuit was encapsulated in an epoxy resin. The electronics was embedded in a plastic nose cone with a metal cap on top of the nose cone which in conjunction with shell body would work as a quarter wave monopole antenna.

The complete electronics was tested for its ruggedness by the drop test. The fuze was fitted on a 25 pound dummy shell and dropped in a guided steel tube over a metal block from the roof top of a 40 feet high building. The electronics withstood the ‘g’ test estimated to be several thousand ‘g’s.

The fuze was powered with a dry battery of 22.5 V. The first few fuzes were designed to function with a 25 pound smoke shell (and tuned to appropriate frequency of oscillator with this shell) at Proof and Experimental Establishment (PXE) at Chandipore on sea at Balasore in Orissa. The fuze in its first firing failed. It was soon discovered from the recovery of the fuzed shells that the fuze had failed due to its defective encapsulation of the battery in wax. Wax as the encapsulant of the battery was replaced with a polyester resin. In the second test carried out with this encapsulation of the battery and without any changes in electronics, in September 1966, the fuze was fired at charge II of 25 pounder shell. The fuze achieved air bursts over the sea as could be seen from the beautiful flash of the smoke shell. The fuze had made a history in September 1966, as this was first successful fuze developed by the DRDO. From this point onwards there was no looking back.The process of improvements to withstand shocks on higher charges were carried out. The fuzes using new nose cones fabricated from glass filled polypropylene were successfully fired with high explosive shells right upto the charge IV of 75/24 Pack-How shell. The sensitivity of the fuzes was improved using optimized oscillator-detector. Also a new reserve battery suggested by the author had been developed by this team during 1969. The system consisted of a single cell using carbon-zinc system with chromic acid/stannic chloride electrolyte in conjunction with a DC-DC converter capable of satisfactory operation from 1.5 volts. This was the first development of a single cell battery in India and perhaps in the world for fuze applications, as no other fuze was known to have used a single cell system.

Concurrent with the development of the fuze, a new technique called the hoist gear technique was developed in end 1966. The author and his team developed a completely new system of measuring the oscillator sensitivity of fuzes wherein the oscillator transmitted its own collector current information to a ground telemetry receiver. The shell was hoisted above the ground over a water pond and suspended with a nylon rope and moved over few wavelengths at a mean height of about ten metres, variations in the oscillator collector current was monitored by a telemetry receiver..This was a new innovation far superior to various contemporary methods of determining the fuze sensitivity .

The technical trials of the fuze were conducted at PXE, Balasore in March 1971 and School of Artillery, Devlali in May 1971, more than a hundred fuzes were fired with a success rate of 90 per cent. The first phase of user trials was conducted at Devlali in September 1971, more than hundred fuzes were fired with a success of 80 per cent. The analysis of the user trial results indicated that the fuze did not meet the reliability requirements at higher charges. This was intriguing as the fuze had undergone a successful technical trial. Investigations and improvements were carried out. In the phase II of user trials at Devlali, fifty fuzes were fired and forty eight fuzes functioned perfectly. Having met the GSQR, the fuze was formally accepted by the user for its induction into services. The fuze technology was transferred to Hindustan Aeronautic Laboratory (HAL), Hyderabad in 1973. In 1974, HAL fired a pre-production lot of fuzes successfully. The manufacturing agency produced several thousand fuzes subsequently.

The team later in 1975 developed a 4.5” Naval anti-aircraft fuze in a record nine months period and tested it at PXE, Balasore against a standard metal sphere. Interestingly in one of the tests carried out at that time when a foreign made 4.5” fuzes was also being tested at the range, the indigenous fuze produced better results than the imported fuzes. Nine of ten fuzes functioned in the proximity of the spherical target.

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