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Radar Signal Simulation

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***Abstract*—Simulation and analysis of Radar signals is useful for Electronic Warfare Systems to evaluate their performance before going to the war filed. Usually Electronic Warfare (EW) systems are wideband, so we simulate Radar signals with different modulations and radiate them with different scan patterns at wide range of frequencies infinitesimally to evaluate Electronic Warfare System performance. EW system should be robust in Warfield scenario. Radar Signal Simulator is the system developed to generate radar signals in real time scenario to test the EW systems performance. By using Radar Signal Simulator (RSS), we can simulate different types of radar signals and can generate them in real time. FTS is configured with a high end computer, Systemvue software, Arbitrary Waveform Generator (AWG) and Vector Signal Generator (VSG). AWG and VSG together generate the radar signals with the help of systemvue in microwave or RF ranges. The simulated models of radar signals when downloaded into the hardware AWG and VSG they generate real time radar signals of microwave frequencies.**

Key words: Electronic Warfare systems, radar signal modulations, scan patterns, AWG and VSG

I INTRODUCTION

Electronic warfare (EW) is defined as the usage of electromagnetic spectrum to detect, interpret, analyse and locate the enemy assaults via the spectrum and to impede the enemy attacks through spectrum. The purpose of electronic warfare is to deny the opponent advantages and ensure friendly unimpeded access to the electromagnetic (EM) spectrum.

EW systems are fast and have parallel processing abilities, because it has to take decision before the return of echoes to the receiver of that electromagnetic emission. The emerging need for the military forces to have unimpeded access to the electromagnetic spectrum creates vulnerabilities and opportunities for the electronic warfare (EW) in support for military operations.EW can be operated from land, sea, air and space by manned and unmanned systems.

EW systems are electronic signal intelligence (ELINT) systems that gather information required for electronic attack (EA) and electronic protection (EP). Electronic Warfare includes major subdivisions such as electronic attack (EA), electronic support measure (ESM) and electronic protection (EP).

II CLASSIFICATION OF EW SYSTEMS

It is classified into electronic support measure (ESM), electronic attack (EA) and electronic protection (EP).

A.ELECTRONIC SUPPORT MEASURE(ESM)

Electronic support measure is an action which detects, identifies, locates and interprets the electromagnetic emissions which are unfriendly. It identifies the radiations or emissions and confirms whether it is friend or foe. It can detect and identify the type of radar mode, scan, modulations...etc from parameters of the received pulse such as pulse width, pulse amplitude, direction of arrival (DOA), time of arrival (TOA), pulse repetition interval (PRI), etc.,

B.ELECTRONIC ATTACK (EA)

Electronic attack is defined as the usage of directed electromagnetic energy intended towards the enemy systems in order to reduce their combat capabilities. It involves technique like noise jamming and deception jamming.ESM gives information required for EA and attack will be done with the directed electromagnetic energy.

Noise jamming is the technique in which noise is added to the intended electromagnetic spectrum to reduce the efficiency of enemy's spectrum usage.

Deception jamming is the technique in which the received copy of spectrum is stored and retransmitted at random intervals of time to confuse the opponent with false indications of our range and position.

C.ELECTRONIC PROTECTION (EP)

Electronic protection is defined as the ability to use the electromagnetic spectrum efficiently even in the presence of enemy's assaults with intended electromagnetic emission aiming us. It provides the better environment for our warfare in the electromagnetic environment where we can deny the assaults of opponent and can use the spectrum efficiently.

ESM provides information required to know about jamming and spoofing, so that our EW system can counter the electronic attack of opponent .Hence EP is also called as electronic counter counter measures (ECCM).

The techniques followed to escape from the electromagnetic attack of opponent are generally side lobe reduction and agility [1].

III RADAR SIGNALS AND ANTENNA SCAN PATTERNS

Pulse radars have good range resolution. Generally the pulse radar signal looks like shown in the Figure-1.

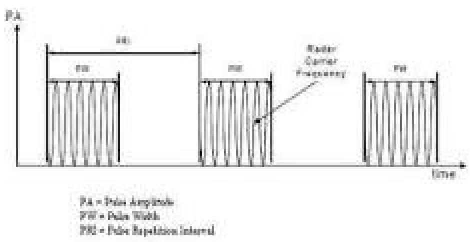

Figure-1: Simple radar pulse

Generally radar signals are very wideband. The WB operation of an electronic system is defined by its Band Width Ratio and is mathematically [6], given by

$$BWR = \frac{2(f_h - f_l)}{f_h + f_l}$$

> 0.2 *(FCC)*
> 0.25 *(DARPA)* **(1)**

& the band width of operation should be greater than 500 KHz. The definition is pictorially shown at Figure-2.

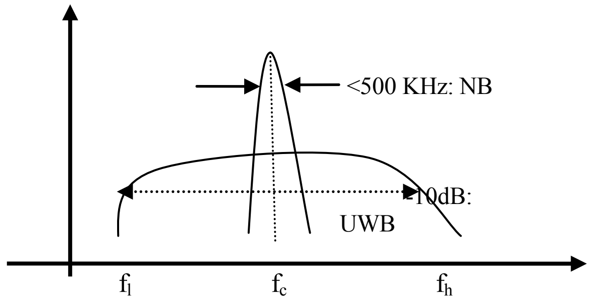

Figure-2: FCC definition of NB & UWB systems

EW systems practically, operate in few thousands of MHz bandwidths, for example, 16000 MHz or 18000 MHz (BWR>8), are truly UWB systems. Antennas and RF & MW front end hardware used in these systems are also UWB components, operating with the same BWR.

NATO designations of radar bands are shown in the Figure-3.

PDF To Go

Band Designation	Frequency, GHz	Wavelength, cm
A band	To 0.25	to 120
B band	0.250-0.5	120 to 600
C band	0.5 -1	600 to 300
D band	1-2	300 to 150
E band	2-3	150 to 100
F band	3-4	100 to 75
G band	4-6	75 to 5
H band	6-8	5 to 3.75
I band	8-10	3.75 to 3
J band	10-20	3 to 1.5
K band	20-40	1.5 to 0.75
L band	40-60	0.75 to 0.5
M band	60-100	0.5 to 3

Figure-3: Radar NATO designations [6]

In fact in radars, range resolution will be better when we have high bandwidth, but in order to have high bandwidth the pulse width should be reduced. When pulse width reduces, no sufficient energy is incident on target by radar to illuminate it to get information. So one of better technique is to achieve range resolution with high bandwidth and to retain the energy of a long pulse simultaneously is the pulse compression. Different pulse compression techniques are linear frequency modulation (LFM), phase coded waveforms like Barker codes, Huffman coding etc. All these techniques are used by Modern radars.

A. LINEAR FREQUENCY MODULATION (LFM)

When a radar signal undergoes linear frequency modulation maximum compression of pulse takes place. In a linear frequency modulation [2] the frequency of a carrier increases instantaneously called Chirp up or instantaneously decreases called Chirp down. The LFM radar pulse is shown in the Figure-4.

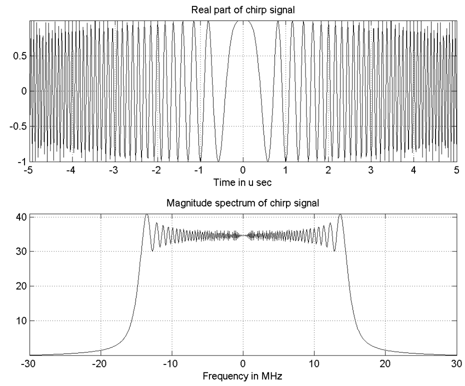

Figure-4: LFM radar pulse in time and frequency domain

B. BARKER CODE

Barker codes [3] are the finite sequence of +1 and -1 also represented can be in + and - , which indicates phase changes. In barker sequences the pulse compression ratio is small compared to LFM. The fixed barker code sequences are 2, 3, 4, 5, 7, 11 and 13. The barker coded radar signal is shown in the Figure-5.

LENGTH	CODES	
2	+1−1	+1+1
3	+1+1−1	
4	+1−1+1+1	+1−1−1−1
5	+1+1+1−1+1	
7	+1+1+1−1−1+1−1	
11	+1+1+1−1−1−1+1−1−1+1−1	
13	+1+1+1+1+1−1−1+1+1−1+1−1+1	

(a)

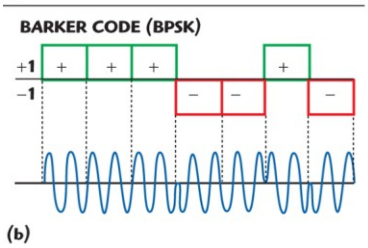

Figure-5: Barker code sequences and barker coded radar signal waveform

C. RADAR ANTENNA SCAN PATTERNS

Antenna's radiation pattern is the instantaneous field view of the radar. Typically 3dB beam widths both in azimuthal and elevation, of the antenna are used to calculate the visible part of space for radar. The coverage of antenna beam width is not sufficient for radar's requirement. To overcome this radar antenna has to steer electronically or mechanically in space. Every radar uses different search and track strategies. These search strategies are called antenna scan type (AST) of the radar. The commonly encountered scan types are circular, helical, raster, sector, conical...etc.

On reception of radar pulse the ESM system analyse, calculate and interpret the parameters so that it can determine the mode of operation such as search or tracking, antenna scan pattern, frequency of radar ,position and modulations involved. Those parameters are pulse amplitude, pulse repetition interval (PRI), pulse width (PW), direction of arrival (DOA), TOA (time of arrival). These parameters give information about type of radar which emitted the pulse that EW system received. By using difference between TOA of radar antenna power levels or peaks received antenna scan period (ASP) can be determined. Similarly by calculating difference between TOAs of successive radar pulses PRI can be determined. Different types of radar antenna scans are shown in the Figure-6.

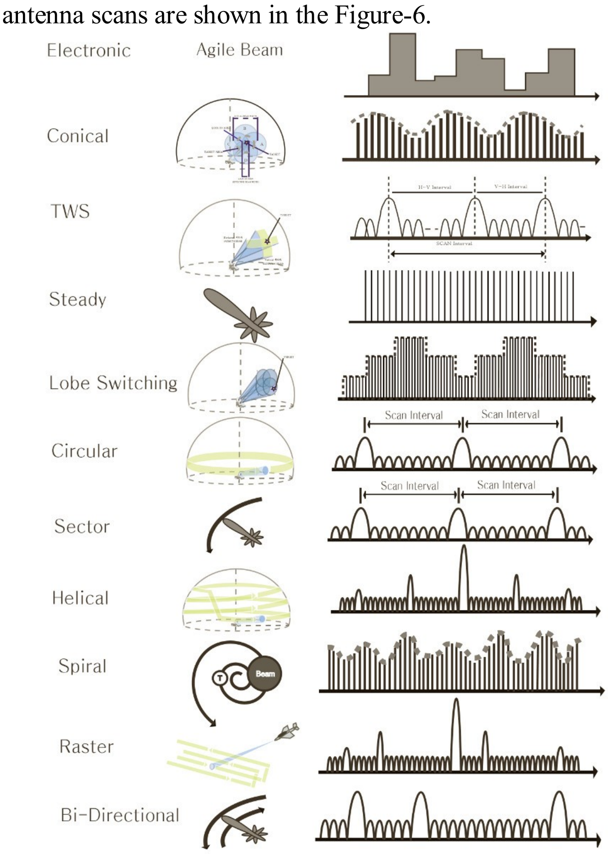

Figure-6:Scan patterns of different scans [6]

For example consider circular and sector scans whose Pulse Amplitudes (PA) vs. TOA graphs and main beam positions are shown in the Figure-7 and Figure-8 respectively.

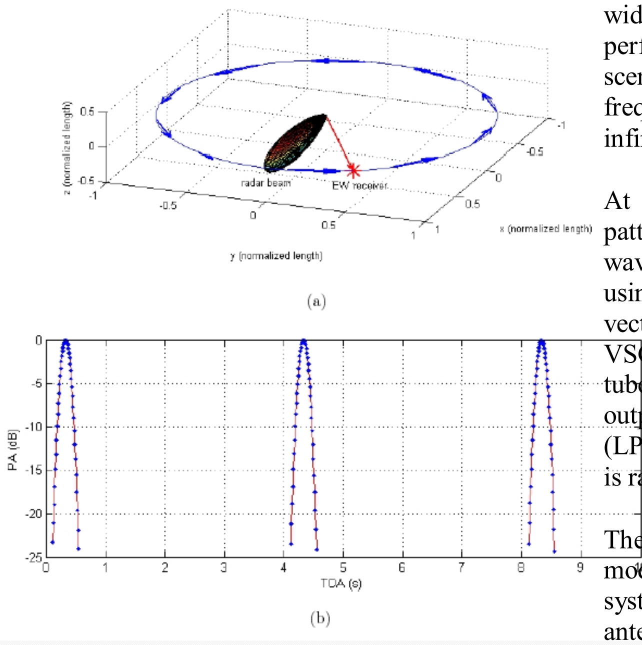

Figure-7: Circular scan main beam position in Fig.(a) and PA vs. TOA in Fig.(b).

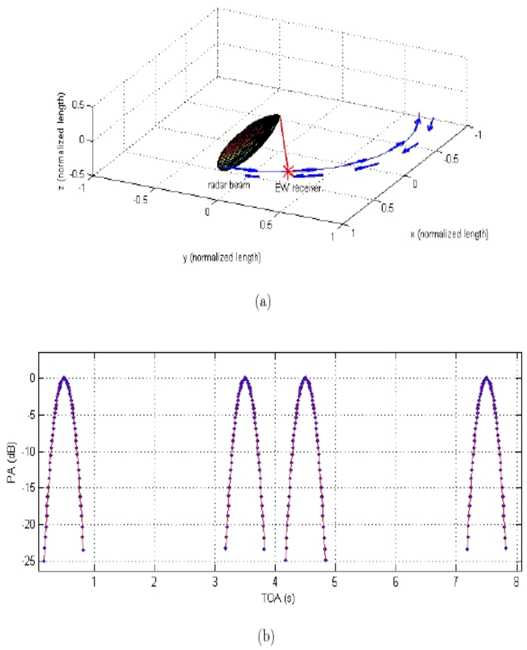

Figure-8: Sector scan's main beam position in Fig. (a) and its PA vs. TOA graph in Fig. (b).

In the above figures the interval between two pulses gives ASP (antenna scan period). For sector scan it scans a target to back and forth so in a one antenna scan period will get two main beams in this type [4].

IV RADAR SIGNAL SIMULATOR

Radar Signal Simulator (RSS) simulates different radar signals with different modulations, scan patterns. These are of wide band signals, more than few GHz, because EW systems are operated over wide band. RSS is the system designed to test the performance of the EW systems in real field scenario. It generates wideband radar signals at each frequency our EW system performance is evaluated infinitesimally.

At first RSS simulates radar signals and scan patterns using software system vue. These waveforms are transformed to real time scenario using auxiliary wave form generator (AWG) and vector signal generator combined (VSG). From the VSG the RF output is given to the travelling wave tube amplifier (TWTA). The amplified version of output is given to the Log Periodic Dipole Antenna (LPDA) or parabolic reflector antenna from where it is radiated into space.

There are many ways to generate radar signal models with RSS, one way is to keep fixed RSS system antenna in line of sight with the receiving antenna of our EW system or observation system. The second is when transmitting and receiving antennas are in line of sight the radiation pattern is obtained by controlling the radiated power through software interfaced to hardware. This method is used in this work.

A. SYSTEM VUE

System Vue is electronic system level design software that allows the system architect and algorithm developers to innovate the next generation of wireless / aerospace / defence communications. System vue has got different libraries including radar library which facilitates to design the model for radar signal and scan pattern simulations easy [6].

B. ARBITRARY WAVEFORM GENERATOR

Arbitrary waveform generator (AWG), when the design models downloaded into its hardware interfaced to system vue it generates waveforms. These waveforms need to be up converted to RF or microwave frequencies.AWG is interfaced to system vue in the PC and also connected to VSG (vector signal generator).Below 5GHz it acts as direct signal generator and for above 5GHz it acts as baseband generator. The output of AWG has I, Q, I^{-} and Q^{-} [6].

C. VECTOR SIGNAL GENERATOR

Vector Signal Generator (VSG) has inputs I, Q, I^{-} and Q^{-}, that is for in phase, quadrature phase, and differential in phase and differential quadrature phase. When AWG generated waveforms are given as input to VSG it modulates or up-coverts the waveforms into RF or microwave frequencies [5].

D. SIMULATION SCHEMATICS DEVELOPED WITH SYSTEM VUE

We developed some simulation schematics of Linear Frequency Modulated (LFM) Pulse and antenna scan patterns of simple radar pulse such as circular, and raster.

LFM pulse simulated with frequency 70MHz, pulse width 10microseconds and pulse repetition interval 100microsecondsshown in the Figure-9.

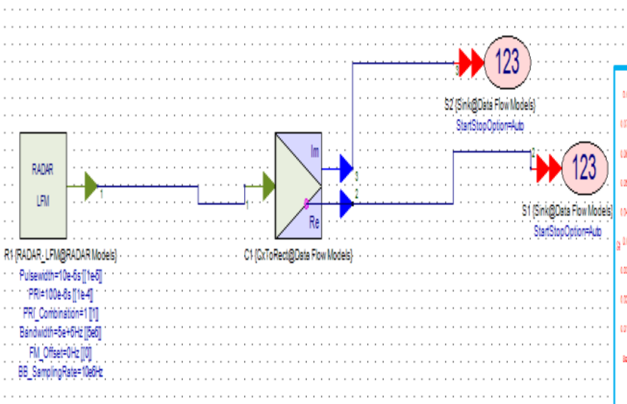

Figure-9 (a): Radar LFM pulse design model

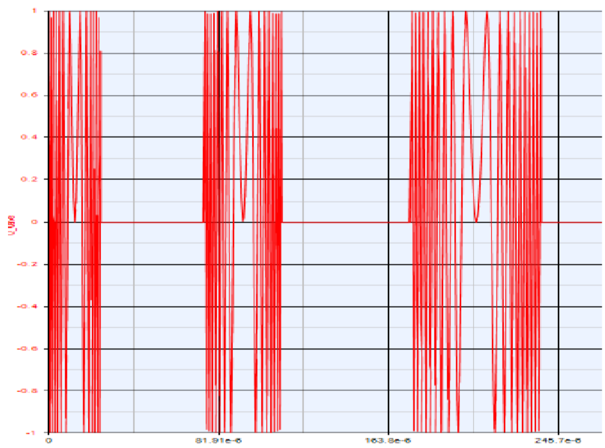

Figure-9 (b): LFM pulse waveform

Circular scan pattern simulated with specifications frequency 9GHz, pulse width 500 nanoseconds, and pulse repetition interval 10 microseconds, antenna radiation pattern circular of duration 5seconds shown in the Figure-10.

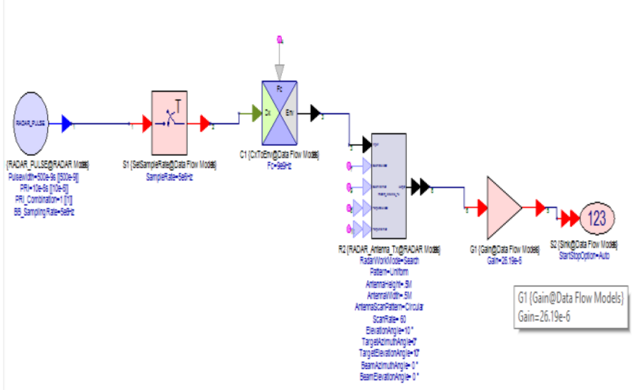

Figure-10 (a): Radar circular scan design model

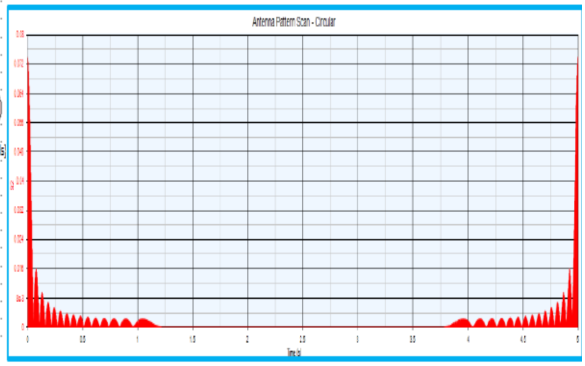

Figure-10 (b): Circular scan pattern waveform

Raster scan pattern with specifications frequency 9GHz, pulse width 500 nanoseconds, pulse repetition interval 10 microseconds, antenna scan period of 6 seconds is shown in the Figure-11.

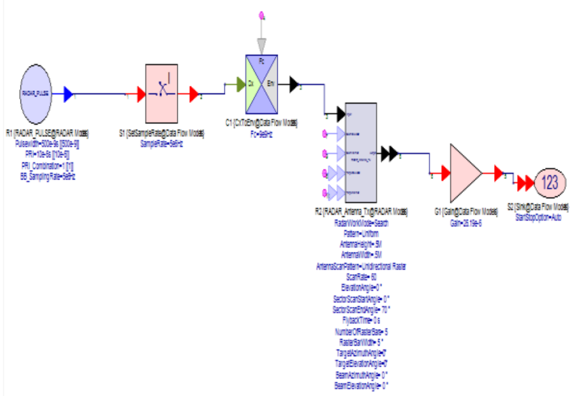

Figure-11 (a): Radar raster scan design model

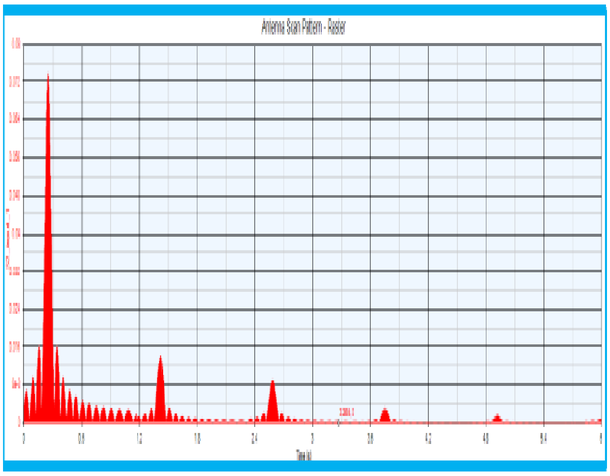

Figure-11 (b): Raster scan pattern waveform

V CONCLUSION

With the help of System vue software loaded in PC and interfaced with the hardware AWG and VSG generates different radar signals with different radiation patterns. With the signals generated by this RSS system, we can test our EW system on a wide range of frequencies thoroughly so that our EW systems can be robust in the field. This enhances the combat capability of the defence forces in the electromagnetic environment of the war scenario. The RSS system has its wide application in the defence forces, where electromagnetic environment of war conditions prevail.

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VII BIODATA OF AUTHOR (S)

Dasari Jeevan Kumar was born in Vijayawada, AndhraPradesh. He completed his schooling and intermediate in Vijayawada itself. He had done his B. Tech from MIC College of Technology located near Vijayawada in Electronics Communications Engineering. After completion of B. Tech., he has undergone a training PG diploma in industrial automation in Chennai. He has qualified in GATE 2011 and presently pursuing M. Tech (Radar and Microwave) in Andhra University College of Engineering, Visakhapatnam, Andhra Pradesh. At present he is doing his project work in Bharat Electronics Limited, Hyderabad, as a part of his M.Tech. Curriculum.

Ch Viswanadham, born in Ampolu, a village in suburbs of Srikakulam, Andhra Pradesh, India joined Bharat Electronics Limited, a premier defense electronics industry in 1990 immediately after B Tech (ECE) from Nagarjuna University, Guntur, and Andhra Pradesh. He worked in various Naval EW Systems from design to field trails. He has received internal R&D award for developing light weight ESM system for Indian Naval Ships. He has been deputed to Israel, Spain & South Korea to participate in technical discussions on EW systems with international companies. He has completed Master's degree in Digital Systems from Osmania University, Hyderabad in 1997, while working at BEL. Presently he is working as Senior Deputy General Manager (D&E) and heading RF & MWP group. He has presented many technical papers in BEL-House journal, national & international journals and conferences. He is Fellow of IETE & IE (I), Life member of SEMCE (I) & CSI and MIEEE. He is pursuing PhD in Andhra University, Visakhapatnam. His areas of interest are antennas, radomes, RF & Microwave designs and wide band / narrow band receivers.

Prof.P.Mallikarjuna Rao was born in 1960.He did his B.E (ECE), M.E (control systems) and PhD (microwave and analog communications) from Andhra university college of engineering (AUCE).He was awarded the best PhD thesis award in 1999.he guided nearly 105 M.E/M.Tech projects .He is a fellow member of IETE and life member of SEMCE (I) and ISTE.At present he is working as a professor in AUCE (autonomous), Visakhapatnam, Andhra Pradesh.

