Design & Simulation of Channelized RF Front End for Auto Track Receiver applications

V. Satish¹, S.Aruna², P.Mallikarjuna Rao³, Ch. Viswanadham⁴

¹Student, M. Tech, Department of ECE, Andhra University, Visakhapatnam, India – 530003.
²Assistant Professor, ³Professor, Department of ECE, AUCE (A), Andhra University, Visakhapatnam, India – 530003.
⁴Senior Deputy General Manager, Bharat Electronics, IE, Nacharam, Hyderabad, India – 500076.

Abstract—ECM is branch of EW Systems and is used to jam the radars to make it ineffective during the peace and war scenarios. To jam the radars, we need to transmit the jamming signals in proper direction. The jamming signals include high power noise or delayed RF pulses. The high power noise is generated and is transmitted through ECM antenna. To make the jamming more effective, the transmitting antenna has to be positioned to the desired direction during jamming. Thus we need auto track receiver to position the jamming antenna in the desired direction during jamming. The tracking has to be done automatically in the direction of radar signals with good tracking accuracy to have effective jamming. This can happen only through high speed tracking receiver circuits and suitable algorithm. A set of antennas receive RF signals radiated by radars. The RF signals received by the antennas are given to the down converters which converts the high frequency of RF signal to low frequencies, i.e., IF signals. The down converted signals are sent to the digital receiver. The receiver output contains error signal, which is identified by the error detector and error is corrected by changing the angle of antenna to the object line of sight automatically by using servo motors. In the current paper, the RF front end required for ATR is presented.

Key Words: Electronic warfare, Electronic support measures, Electronic countermeasures, Advanced Design System (ADS).

I DEFINITION

1. ELECTRONIC WARFARE

Electronic warfare is defined as, “a military action involving the use of electromagnetic energy to determine, exploit, reduce, or prevent hostile use of the electromagnetic spectrum and action which retains friendly use of the electromagnetic spectrum space” [1].

2. RADAR EW:

Armed forces use radar in both defensive and offensive weapon systems. Reflected RF echoes of the target are used to measures target range. Bearing and elevation and determine target location. Radar uses RF transmission ranging from high frequency (HF) to millimeter waves (30MHz-95GHz). The frequencies are designed by various alphabetical letters. New band designations are given in Table-1. Modulated RF signals may be pulsed or continuous wave (CW). Radar function includes target detection, acquisition, tracking and navigation. Radar extracts range, bearing and speed of a target. Radar information’s used for launch and control of weapons like missile, air defense gun, etc. Modern advancements include phase array antenna, complex modulation on the radar, low probability of intercept radar, improved signal processing to extract data from highly corrupted echo signal, etc. Radar EW involves extraction of detailed information of radar signals emitted, use of this information either to formulate electronic order of battle (EOB) or provide the information to a jammer to operate in an efficient way [1-2].

<table>
<thead>
<tr>
<th>Band</th>
<th>Frequency range</th>
</tr>
</thead>
<tbody>
<tr>
<td>A band</td>
<td>0 to 0.25 GHz</td>
</tr>
<tr>
<td>B band</td>
<td>0.25 to 0.5 GHz</td>
</tr>
<tr>
<td>C band</td>
<td>0.5 to 1.0 GHz</td>
</tr>
<tr>
<td>D band</td>
<td>1 to 2 GHz</td>
</tr>
<tr>
<td>E band</td>
<td>2 to 3 GHz</td>
</tr>
<tr>
<td>F band</td>
<td>3 to 4 GHz</td>
</tr>
<tr>
<td>G band</td>
<td>4 to 6 GHz</td>
</tr>
<tr>
<td>H band</td>
<td>6 to 8 GHz</td>
</tr>
<tr>
<td>I band</td>
<td>8 to 10 GHz</td>
</tr>
<tr>
<td>J band</td>
<td>10 to 20 GHz</td>
</tr>
<tr>
<td>K band</td>
<td>20 to 40 GHz</td>
</tr>
<tr>
<td>L band</td>
<td>40 to 60 GHz</td>
</tr>
<tr>
<td>M band</td>
<td>60 to 100 GHz</td>
</tr>
</tbody>
</table>

Table 1: Radar Electronic warfare (EW): NATO frequency designations

II FUNCTIONAL CLASSIFICATIONS

EW is classified based on functionality into three groups electronic support (ES) electronic attack (EA), electronic self protection (EP), these are the new names given to
Electromagnetic support measures (ESM), Electromagnetic counter measures (ECM), Electromagnetic counter counter measures (ECCM) [1-4].

![Electronic Warfare Classification](image)

**Figure-1:** Electronic Warfare is classified into ESM, ECM, ECCM

**A. Electronic Support Measures (ESM)**

ESM is "the division of electronic warfare involving actions taken to search for, intercept, locate, record, and analyze radiated electromagnetic energy for the purpose of exploiting such radiations in the support of military operations" [1-2].

**B. Electronic Counter Measures (ECM)**

ECM is "the division of electronic warfare involving actions taken to prevent or reduce an enemy’s effective use of electromagnetic spectrum". ECM consists of two types. First is jamming and the second is deception. ECM is used to jamming, chaff and flares to interference with the operation of radars, military communication, and heat seeking weapons [1-4].

**C. Electronic counter-Counter Measures (ECCM)**

ECCM “is the division of electronic warfare involving actions taken to insure friendly effective use of the electromagnetic spectrum despite the enemy’s use of electronic warfare”, ECCM defined as measures taken in the design or operation of radars or communication systems to counter the effects of ECM [1-2].

**III MONO PULSE AUTO TRACKING RECEIVER**

Mono pulse tracking is referring to the “ability of obtaining error correction information on a single pulse radiated by the radar”. Mono pulse tracking uses phase comparison or amplitude comparison techniques [5-6]. In this work, we will use amplitude comparison technique, simple and cost effective. The basic diagram of the proposed work is given in Figure-2.

**IV BLOCK DIAGRAM**

We use parabolic reflector antenna for transmission because of its high directivity in one particular direction. It can produce the narrowest beam widths. The reflector antenna is mounted on movable platform. Horn antennas are widely used in EW applications because of its simplicity in construction, large gain etc. [1, 7]. The present work utilizes four horn antennas in receiving mode. Antennas receives RF signal from the free space, one pair for azimuth correction and the other for elevation correction. The radar signals are collected and down converted by RF section after sufficient amplification. By using the digital receivers, the down converted RF signal i.e., IF is processed to get the angle error. After calculating error for both azimuth and elevation, it is corrected by rotating the antenna automatically to the object line of sight with the help of servo motors.

![Block Diagram](image)

**Figure-2:** Basic diagram of Mono pulse auto tracking receiver

The block diagram is worked in two parts, RF part and DSP part. The RF part is given at Figure-3. This block diagram is for one channel and four such channels are required for mono-pulse auto tracking receiver.

The Channelized Receiver is a narrow band receiver operating in C/D band required for an ECM. The unit shall have four similar channels & are to be connected to 4 receiving antennas (normally horn antenna) mounted on a single parabolic reflector antenna and provides the signals in the intermediate frequency (IF) range of 750 to 1250MHz. It also provides Video signals corresponding to the different bands which can be used for selecting the band of interest. It also built in with set of switch filters, so that cell frequencies can be eliminated through proper selection of the switch. The dynamic range of the unit can be extended by using a programmable digital attenuator. It is an ideal front end module for a 500 MHz digital receiver, to extract the error information on pulse to pulse basis.
Channelized Receiver uses up/down conversion super heterodyne technique. It meets high sensitivity, wide spurious free dynamic range and good selectivity over the frequency range of C/D band. It consists of pre-selection section and RF-IF Converter section. Pre-Selection Section consists of 6 sub octave band pass filters to get good image rejection and better sensitivity. Depending on the incoming signal frequency, only one filter will be selected at a time. Full band is covered using the C/D band pass filter. The RF/IF converter is realized in two sections, up converter section and down converter section. The incoming signal is limited and passed through pre-selector filters with amplification. In RF/IF Up converter, the RF Signal is up converted to first IF of 5.5-6 GHz using a first local Oscillator LO1 selectable from frequencies of 0.6, 0.7 & 0.75GHz. This IF-1 signal is filtered, amplified and applied to down converter section. In RF/IF down converter section the first IF (IF-1) of 5500 - 6000MHz is down converted to 1000MHz IF using a second fixed local oscillator of frequency of 6750MHz. The second converter output 1000±250MHz is filtered and amplified to get sufficient selectivity and gain. Before manufacturing of the above block diagram, the same is simulated for characterization.

V SIMULATION USING ADS
Software tool used in this project is ADS (Advanced Design System). ADS provide a vast array of simulation modes and models. For design of this project, we use mostly s-parameter simulation and EM simulation in the software. Since ADS is oriented toward microwave applications, we find that it contains a much larger library of transmission line and passive component models that include non idealities of these components. If we didn’t get the required output we can optimize or tune the circuit to get the desired output [8].

A. Tuning and optimization

It is often the case that our manually calculated values do not provide the most optimum performance and it is needed to change the component values. This can be done in two ways: Tuning or Optimization [8].

1. Tuning:
Tuning is a way in which we can change the component values and see the impact of the same on circuit performance. This is a manual way of achieving the required performance from a circuit which works well in certain cases.

2. Optimization:
Optimization is an automated procedure of achieving the circuit performance in which ADS can modify the circuit component values in order to meet the specific optimization goals. Please note that care should be taken...
while setting up the goals to be achieved and it should be practically possible else it will not be possible to meet the goals. Also the component values which are being optimized should be within the practical limits and this needs to be decided by designers considering the practical limitations [8]. By using this, we are designing the circuit of each component and assembling them together and we will see overall performance of the system for designing of components we are going for microstrip materials, so we should know about microstrip materials, material we are using in this project is RT Duroid 5880.

B. RT Duroid 5880

RT/duroid®5880LZ filled PTFE composites are designed for exacting stripline and microstrip circuit applications. The unique filler results in a low density, lightweight material for high performance weight sensitive applications. The very low dielectric constant of RT/duroid 5880LZ laminates is uniform from panel to panel and is constant over a wide frequency range. Its low dissipation factor extends the usefulness of RT/duroid 5880LZ to Ku-band and above. RT/duroid 5880LZ laminates are easily cut, sheeted and machined to shape. They are resistant to all solvents and reagents, hot or cold, normally used in etching printed circuits or in plating edges and holes. When ordering RT/duroid 5880LZ laminates, it is important to specify dielectric thickness, tolerance, electrodeposited copper foil, and weight of copper foil required. Its dielectric constant of RT Duroid 5880 is 2.2.

C. Simulation Results of Modules

Firstly we have designed each component i.e., BPF, Mixer, Switch, Low noise amplifier based on specifications laid out from the block diagram and the response of the simulated blocks were verified for the results. After designing all the components we had to connect all the components as per the block diagram shown above and see the full module response over the frequency ranges. As the simulation results of all the modules is not possible to present in this paper, few simulation results were presented in the Figures 4–15.

Figure 4: ADS schematic diagram for 0.5-0.7GHz Band pass filter
Figure 5: S-Parameter Response for 0.5-0.7GHz Band pass filter

Figure 6: ADS schematic diagram for 1.8-2.0GHz Band pass filter
Figure 7: S-Parameter Response for 1.8-2.0GHz Band pass filter

Figure 8: ADS schematic diagram for 5.5-6.0GHz Band pass filter
Figure 9: S-Parameter Response for 5.5-6.0GHz Band pass filter

Figure 10: ADS schematic diagram for 1.8GHz Low pass filter
Figure 11: S-Parameter Response for 1.8GHz Low pass filter

Figure 12: ADS schematic diagram for 1.25GHz Low pass filter
Figure 13: S-Parameter Response for 1.25GHz Low pass filter

Figure 14: ADS schematic diagram for 2GHz Low pass filter
After simulation of all individual designs as per the block diagram, all the modules are connected to form the channelized receiver and the response is verified. The output specifications are as per the expected results. The advantage with ADS is that it gives direct fabrication files, called spool files. These files will be used for fabrication of the printed circuits on RT duroid 5880 material. Presently, the units are assembled with components and the test is under progress. The achieved results with these design specifications, will be presented in the next paper.

VI CONCLUSION

RF channel required for mono pulse tracking is designed, which is very useful in military applications to keep the enemies object in line of sight to the transmitting antenna. This is necessary to take action for the frequencies received by the RF front end receiver. The RF signals received were converted to fixed IF, so that digital receiver can be connected for further processing and the block diagram is given clearly. Each component of block diagram is designed and simulated using ADS software. In this paper few filters design schematics and their responses using ADS were shown. The remaining components were also designed and simulated using ADS. The combined response has met all the specifications with respect to the design specifications.

VII REFERENCES


VIII BIO DATA OF AUTHOR (S)

V Satish, born in Kothakota, a village in Visakhapatnam district, Andhra Pradesh. He completed his SSC from Board of Secondary Education in Donbosco’s High
School at Narsipatnam. He has completed his B. Tech (ECE) from JNTUK University in Thandra Paparaya Institute of Science and Technology, Bobbili, Andhra Pradesh. During B.Tech, he actively participated in Training program conducted by JNTU Kakinada, in his college on “Softskills and Employability Skills Training (SET) Program”. After that, he participated National Workshop on “EMBEDDED SYSTEMS” held at GITAM University, Visakhapatnam, Andhra Pradesh. He had successfully completed his B.Tech Main project titled “GSM Cell Phone based Device Monitoring and Controlling System”. Presently, he is pursuing his Master’s degree in Radar & Microwave Engineering from Andhra University, Visakhapatnam, Andhra Pradesh. At present he is doing his project work in BEL (Bharat Electronics Limited) in Hyderabad as a part of his M.Tech academics.

S. Aruna, received the Bachelor of Engineering in Electronics and Communication Engineering from Andhra University and the Master of Engineering in Electronic Instrumentation Engineering from JNTU Kakinada. Currently, she is working as Assistant Professor in the department of Electronics and Communication Engineering, Andhra University College of Engineering (A). She has presented many technical papers in national & international conferences at Canada, Jodhpur and Visakhapatnam. She has attended many Workshops. She is member of IETE & IST. Her Research interests include Array Antennas, EMI/EMC and Soft Computing.

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.

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, 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.