Antenna System for Vehicle Mount GPR

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Abstract:

This paper describes an antenna system for vehicle mount Ground Penetrating Radar (GPR) which is used for detection and 3-D imaging of anti personnel,anti tank mines and IED. The antenna is 1.8 meter long and consists of a Tx antenna row and a Rx antenna row.Each row houses 9 radiating elements arranged in triangular grid.The two rows are aligned at an angle of 40 degree so as to form a monostatic antenna arrangement.Thismonostatic arrangement ensures that targets at lower depth are also illuminated by both transmit and receive antenna.For obtaining required detection depth the radiating element is required to operate over 187% bandwidth with good return loss and stable gain and patternIn addition it should have Tx/Rx antenna coupling between adjacent Tx and Rx antenna < -30 dB so that sufficient gain can be provided in the receiver for small target detection.

Key Words: Vehicle mount GPR,UWBAntenna,Tx/Rx antenna coupling,Radome

I. INTRODUCTION

Avehicle mount GPR system is required for detection and 3-D imaging of anti-personnel mines (APM) anti-tank mines (ATM) and Improvised Explosive Device (IED).The antenna for this GPR system is to be mounted on front side of a vehicle and should contain multiple radiating elements so that a large swath area is scanned simultaneously. The spacing between the elements decides the resolution in the X-Y plane.The depth of detection(in Z direction) is decided by the frequency of operation and usually detection depth is more for lower frequencies[1].Thus lower frequency of operation should start from few 10's of MHz for a detection depth of 2 meters.In addition since the antenna is mounted on a moving platform it should be rugged,lightweight and should be able to operate in different weather conditions like rain,high and low temperatures.

The novelty of this paper is the design of an antenna system for vehicle mount GPR which is compact,rugged,lightweight and suitable for all weather conditions.

II. ANTENNA SYSTEM DESIGN

Based on the requirement of detection depth, resolution and swath area following electrical specifications were set for the Antenna system.

Electrical Specifications:

Operating B.W: 187%

VSWR :< 2:1

Gain :> 1 dB

TX/Rx antenna coupling< -30 dB

Mechanical Specifications:

Weight of antenna system:<25 Kg

Dimension of antenna system:1.8mX0.15mX0.17m

Environmental Specifications:

Antenna should be rain proof

Based on these specification antenna system design was worked out ,which involved design of radiating element,design of antenna configuration and radome.To meet the electrical specification radiating element and antenna configuration was designed on the other hand Radome was designed to make the antenna rain proof.Radome was also designed to be electrically transparent.

The following sections describes these three steps involved in the design of antenna system for Vehicle Mount GPR.

III. RADIATING ELEMENT

Performance of radiating element was already established and it was found to work satisfactory over the required bandwidth[2].Next section gives the details of the radiating element design.Theradiating element is a type of monopole which is machined out of 2 mm thick aluminum plate in the shape of a rugby ball.It is backed by a curved reflector to make it unidirectional.To make this antenna work at frequencies starting from few MH'z and over 187%

bandwidth with VSWR<2:1it is loaded with 150Ω carbon resistors at appropriate places.Figure 1 shows photograph of the radiating element.Figure 2 shows measured return loss for the radiating element.Thefarfield pattern of this element was measured and for this element the beam peak is at 40°in E-plane.

IV. ANTENNA CONFIGURATION

Antenna configuration was worked out based on the requirement of swath area to be covered and resolution in X-Y plane.To achieve resolution of 10cm, elements of Tx and Rx row were arranged in a triangular grid with inter-element spacing of 20cm.To cover required swath area antenna length was required to be 1.8 m.Thus each row was occupied with 9 elements.Since the beam peak for single element is at 40 degree, the Tx and Rx rows were aligned at an angle of 40 degree so that Rx elements are able to receive from the area illuminated by Txelements.Figure3 shows photograph of the antenna.In antenna for the receiver to work at its maximum gain without going into saturationTx/Rxrowcoupling was required to be <-30 dB while measured coupling between Tx/Rx row was -16dB.To reduce coupling, increasing spacing between elements could not be done as it would have changed the resolution.Thus an isolation plate was inserted between theTx and Rx rows [3]and it was covered with flatabsorber.Figure 4 shows antenna with absorber and isolation plate and Figure 5 shows measured return loss of nearest Tx and Rx antenna and their coupling.

I. RADOME

Since the antenna has to operate outdoor in all weather condition it needed to be protected by a Radome which was electrically transparent.TheRadome was designed as a thick film radome in FRP with one way insertion loss < 1dB over the band[4].Figure 6 shows front face of the Radomeasembled with the antenna.TheRadome was designed in five sections, two side section ,two end caps and one centre section.Figure 4 shows different sections of the Radome.This made the fabrication and assembly of Radome with antenna system easier.It also provided easy access to radiating elements.The three sections were held together by screws as well as Adhesive so that the antenna is impervious to rain.ThisRadome was tested for driving rain as per the specification in the table 1.After the test there were no traces of water inside the antenna.

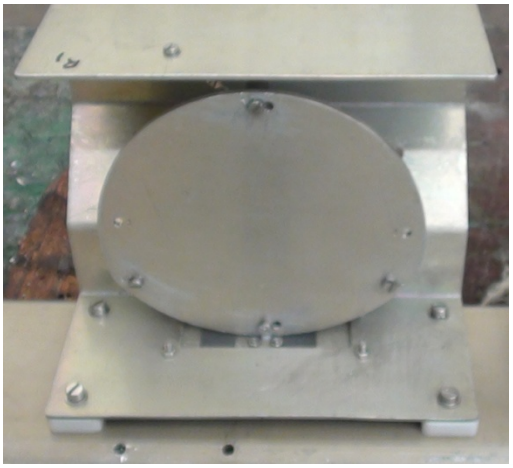
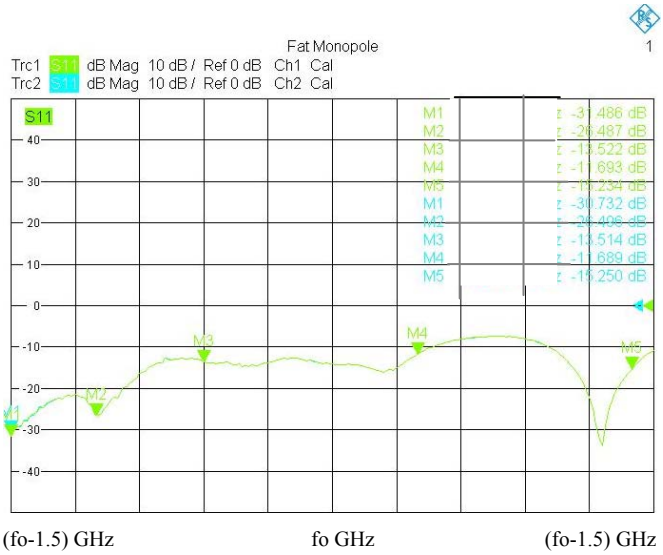


Figure 1 Radiating Element for VM GPR Antenna System



(fo-1.5) GHz fo GHz (fo-1.5) GHz

Figure 2 Measured Return loss of Radiating Element

Figure 3 Photograph of Vehicle Mount Antenna

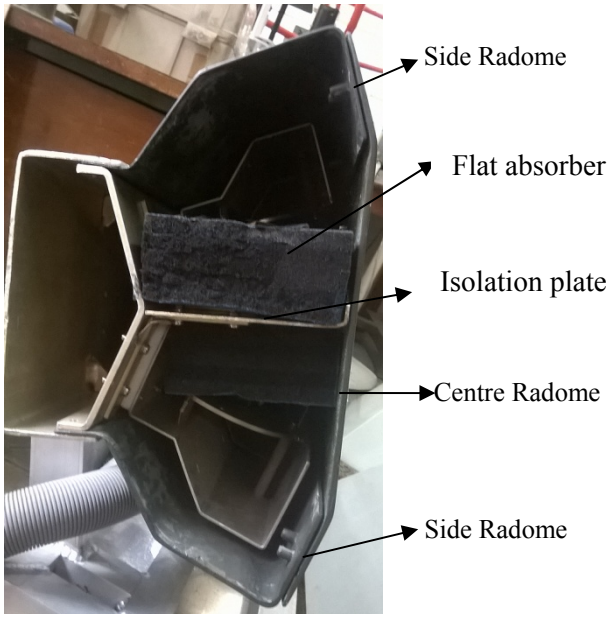


Figure 4 Vehicle Mount Antenna with absorber and Plate

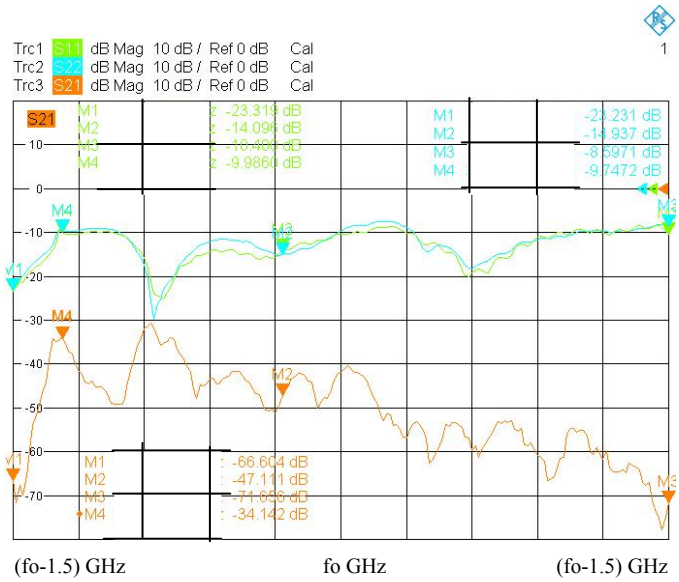


Figure 5 Measured RL and Tx/Rx antenna coupling

Figure 6 Radome Assembled with the antenna

Test No.	Type of Test	Test Conditions (JSS 55555 -2000)		
ET 1	Driving Rain	Rain fall rate	:	250 mm/hr
		Flow rate	:	450 lit/hr
		Static pressure	:	200 kpa
		Duration	:	1 hour
		No. of drops	:	26 drops (One drop on each face, edge and corner)

Table 1: Specification for Driving Rain Test

CONCLUSION

An Antenna System for Vehicle Mount GPR has been designed and Developed with required electrical,mechanical and Environmental specifiications.

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BIODATA OF AUTHORS

Ms. Preeti Dongaonkar received her B.E. in Electronics and Telecommunication Engineering from Pt. Ravishankar University Raipur (C.G.) in 2001 PG Diploma in VLSI Design from ACTS Pune in 2002 and M.Tech in RF and Microwaves from IIT Kharagpurin 2012..She joined DRDO in 2003 where she is working as Sc 'D' in the field of Microwaves and antennas.Her area of interest are UWB Antenna,slotted waveguide antenna ,patch antenna ,compact broadband antenna and computational methods.She is a

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Dr. K. S. Beenamolereceived her Ph.D in Electronics from Osmania University in 2009, M.Tech in Electronics in 1996, from Cochin University of Science and Technology and B.Tech from Mahatma Gandhi University in 1992. Presently she is working as a Scientist in LRDE. Her interests include antenna array synthesis/analysis and development of active antenna array units for Active Phased Array Radars. She is responsible for the cutting edge Technology Development of 'MonopackTransmit*/*Receive *(*T/R)Module' for X-BAND Active Phased Arrays with Industry collaboration. This technology development program on the X-Band have proven the concept and established the first level Technology Base for X-band Active Array development in the country. She is a recipient of the National Research & Development Cooperation (NRDC), India Award 2005, IETE-SmtRanjana Pal Memorial Award-2012 and IETE CDIL Award-2014. She has received DRDO Technology Group Award in 2001 &2010 and Outstanding Team Work Award in 2003. She is a recipient of National Science Day Silicone Medal and Commendation Certificate in 2009. She has received one Patent for her innovative design of Printed Microstrip Patch Antenna Array for Battlefield Surveillance Radar(BFSR-SR) and has applied for two Patents. She has one Copyright. She has published more than 50 research papers in the National/International Journals and Conferences. She is a member of Society of EMC Engineers and Fellow of ATMS and IETE.

Dr. A K Singh obtained his Ph.D. in 1991 in electronics engineering from IT-BHU (now IIT-BHU), Varanasi, India. He joined Electronics & Radar Development Establishment (LRDE), Bangalore in November 1991. Presently he is Outstanding Scientist / Scientist H, Divisional Head of Radar Antenna & Microwave Division and Associate Director of LRDE. He is involved in the design & development of Antenna, RF & Microwave systems for various AESA Radars under development at LRDE/DRDO. Earlier as a Project Director of 3D Low Level Light weight Radar ASLESHA for Indian Air Force , he steered the successful development, user acceptance and production of the radar most suitable for high altitude snow bound mountainous terrains. As a Project Director of AESA Radar for fighters, he has steered the development of Transmit-Receive modules and established necessary design and manufacturing infrastructure in the country to produce large nos. of T/R modules required for different Active Phased array radars. He has established design and manufacturing technology for Multi Beam Antennas required in large numbers for various military radars like Rohini for Air Force, Revathi for Navy, 3D-TCR for Army & 3D-CAR for Akash Weapon System for Airforce& Army. More that 100s of these systems are deployed all over the country to provide required air surveillance. He has also established core antenna technologies for Slotted waveguide Array Antennas for LCA & ALH, Microstrip Array Antennas for UAVs & Missiles, Active Array Antennas and digital arrays for medium range surveillance radars by systematically developing necessary EM design and analysis CAD software packages.

He has served as Chairman, Technical Programme Committee of International radar Symposium (IRSI) in 2007, Chairman IEEE International Symposium on Microwaves in 2009, Chairman IETE conference on RF & wireless in 2010 & 2012, International Correspondent for IEEE Radar Symposium (Germany) in 2008 & 2014. He has authored more than 140 research papers in different international / national journals and symposiums. He has 6 copyrights and 10 patents to his credit. For his significant contributions, he has been awarded NRDC (National Research Development Corporation) meritorious invention award in 1997, DRDO National Science Day commendation in 2005, DRDO Technology Group Award in 2006, DRDO performance excellence award in 2008, IETE-IRSI award in 2009, DRDO AGNI Award of excellence in self reliance in 2010, IEEE International Microwave Symposium Best Paper Award in 2011, best paper award in 2012 & 2013 and IETE-CDIL award in 2014. He is member of academic/research council of IIT Roorkee, IIT BHU & NAL. Dr Singh is editorial board member / reviewer of many peer reviewed journals and Ph.D. examiner in many institutes like IISc, IITs & other institutes. He is a Fellow of IETE, Senior Member of IEEE and Member of Society of Electronics Engineers.