UWB Antenna System with TX/RX Isolation for SFCW GPR

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Abstract:

Stepped Frequency Continuous Wave (SFCW) GPR uses separate antenna for transmission and reception[1].Since in SFCWGPR transmit antenna (Tx antenna) is continuously transmittingand receiver antenna(Rx antenna) is receiving there should be high isolation between Tx and Rx antenna so that receiver does not get saturated.High Tx/Rx antenna isolation also ensures that weak reflections from the nearby target are not masked by strong Tx/Rx antenna coupling.This paper brings out a simple technique of reducing the Tx/Rx antenna coupling.This technique does not require change in Tx/Rx antenna design and was found to improve the input impedance matching,pattern bandwidth and gain of antenna.

Key Words: SFCW GPR,UWBAntenna,Tx/Rx antenna coupling

I. INTRODUCTION

Ahandheld GPR based on SFCW concept is being developed for detection of anti-personnel mines (APM) and anti-tank mines (ATM) and Improvised Explosive Device (IED).This GPR should operate in different types of soils like desert,laterite,red,alluvial and black soil.It should be lightweight and compact in size and should be suitable for single person operation.

Based on requirement of detection depth and resolution and considering loss various across frequency in various soils it was decided to start GPR operation from 100’s of MHz till few GHz covering a bandwidth of 150%.Antenna being one of the most critical component of this GPR system it needed to be compact and lightweight.The antenna was also required to have a Return Loss < -10 dB over 150% bandwidth with a good pattern stability and gain.

An UWB antenna element operating over 150% bandwidth was designed for this handheld SFCW GPR[2].It is a type of monopole with a combination of triangular and elliptical shape to achieve ultrawidebandwidth.The size of UWB antenna element was 135mmx60mm and it was printed on a 62 mil RT Duriod 5880 substrate.Figure 1 shows front and back side of UWB antennaPCB.Figure 2 shows two such elements for Tx and Rx backed by a reflector and housed in a radome.The worst case coupling between Tx and Rx antenna was measured to be -14 dB as shown in Figure3.This antenna was connected to Vector Network analyzer and experiments were done with this antenna for detection of APM,ATM and IED’s using SFCW mode in Vector Network analyzer.In these experiments vector network analyzer was used as a exciter as well as receiver.Results of experiment was collected as S-parameter data and this data was used as input for detection algorithm.SuccessfulDectection of APM,ATM and IED’s was done using UWB antenna and vector Network Analyzer.

In the next step network analyzer was replaced with receiver, exciter and SP card which were much compact than vector network analyzer.In the second set of experiments it was possible to detect APM’s only upto few cm’s and it was decided to increase the receiver gain to increase detection depth.This required recucing the Tx/Rx antenna coupling to at least -30 dB from -14 dB over 150% bandwidth so that receiver does not go into saturation.

II. DESIGN CONSTRAINT

Since the antenna was for a handheld GPR it needed to be lightweight and compact hence it was required that any change done in antenna design to reduce Tx/Rx antenna coupling should not add extra weight or increase volume of the antenna.

III. Tx/Rx ANTENNA DESIGN

To reduce Tx/Rx antenna coupling,design of archimedian spiral[3] and logarithamic spiral antenna[3],[4] was attempted.Since in spiral antenna coupling can be reduced by reversing the sense of polarization for the Tx and Rx antenna element coupling of the order of -25dB could be easily achieved.But the spiral antenna needs a transition to be designed to transform spiral input impedance of 188 ohms to 50 ohm transmission line[5].A spiral antenna also needs a cavity to make its radiation unidirectional. Due to this,size of the designed spiral antenna was too large (single element dimension :17cmx17cmx7cm) hence it was not found to be a suitable option.

Since no other antenna element could be realized with size suitable for handheld GPR with good isolation, attempts were made to apply some technique to existing UWB antenna element to reduce TX/Rx antenna coupling.

a) **Resistive loading of monopole** :Tx and Rx antenna was loaded with resistors of 150ohm.This was able to reduce the Tx/Rx antenna coupling at some frequencies but not over the band and it also reduced gain at lower frequencies drastically.

b) **Three element configuration**: Two Tx elements were fed out of phase so that their coupling cancels at the Rx element[6].This method was able to reduce coupling only over a narrow bandwidth on the other hand size of the antenna system was increased, hence this method was not found suitable.

c) Partition by an isolation plate : An aluminium plate was inserted between Tx and Rx antenna[7], this reduced coupling to <-20 dB throughout the band but deteriorated Return loss performance of Tx and Rx antenna.

d) **Partition by an isolation plate and absorber loading:** Finally an isolation plate was inserted between Tx/Rx antenna elements and isolation plate and Tx and Rx antenna elements were covered with flat absorber having reflectivity better than -17 dB.This technique was able to reduce Tx/Rx antenna coupling to -30 dB over the full band of 150%.Figure 4 shows the photograph of the antenna and Figure 5 shows measured Return loss atTx and Rxantenna port and Tx/Rx antennacoupling.

The pattern and gain of the antenna with isolation plate and flat absorber (Ver2) was measured and it was found that the pattern has become more stable with frequency and gain has improved as compared to Ver1(without plate and absorber).Table 1 gives comparison of gain for antenna Ver1 and Ver2.

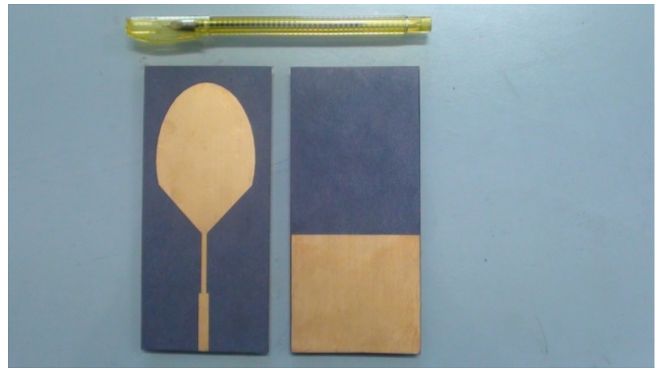

Figure 1UWB Antenna front and back side

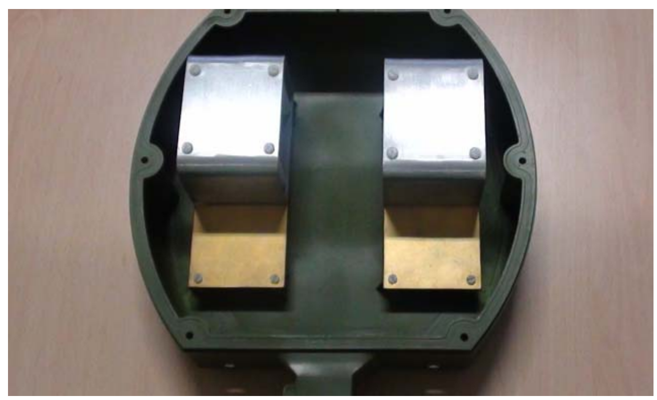

Figure 2 Tx/Rx antenna elements housed in Radome

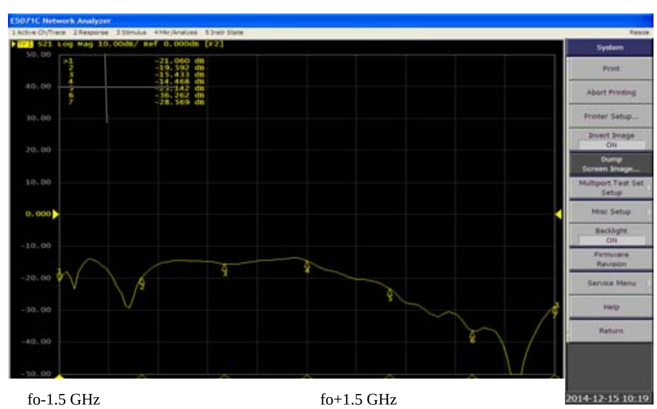

Figure 3 Tx/Rx antenna coupling

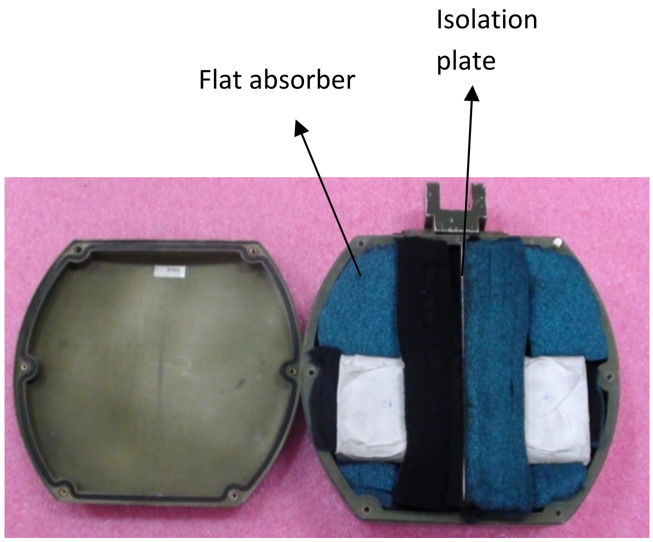

Figure 4 Tx/Rx antenna with isolation plate and absorber

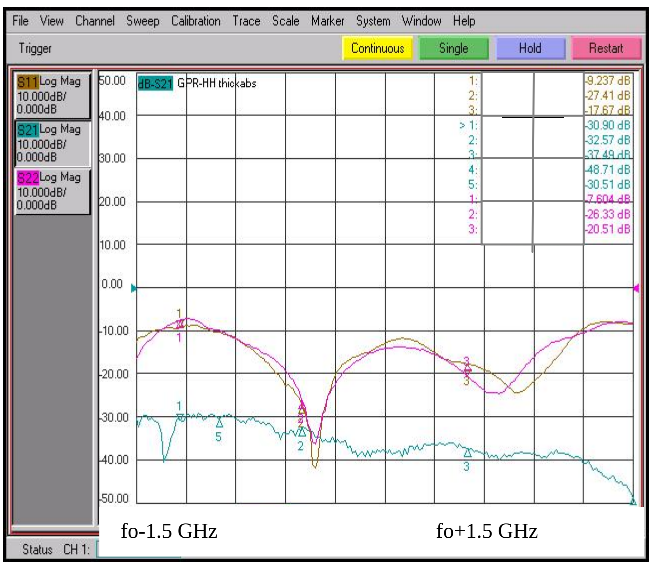

Figure 5 Measured Tx/Rx Antenna coupling and RL with Isolation plate and flat absorber

S.No.	Frequency	Gain (Ver 1)	Gain (Ver 2)
1	(fo-1) GHz	1.93 dB	5.6 dB
2	(fo-0.5) GHz	5.89 dB	7.3 dB
3	fo GHz	4.81 dB	4.5 dB
4	(fo+0.5)GHz	4.07dB	4.7dB
5	(fo+1) GHz	1.72 dB	4 dB
6	(fo+1.5)GHz	0.881 dB	2 dB

Table : Measured Gain for Ver1 and Ver 2 antenna

CONCLUSION

A simple technique for improving Tx/Rx antenna coupling is demonstrated which is able to improve antenna coupling over the 150% bandwidth with improvement in gain and pattern bandwidth.

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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 recipient of DRDO Technology Group Award in 2006 and DRDO AGNI Award of excellence in self- reliance in 2010.

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.