

Internal Technical Report GMRT/GAB/R308-Apr 2022

# Modification and Validation Testing of the GAB Control Parameters

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**Objective:** The GAB LO system in synthesizer mode was earlier working for default Reference LO, and Step-Size values of 10 MHz, and 10 KHz respectively. The **ADF4351** *wideband PLL synthesizer with a integrated VCO* used in GAB system allows reference LO settings from 10 to 250 MHz, and Step-size (Channel Resolution) from 10 to 1000 KHz. To enable custom settings for Reference LO, and Step-sizes using the Web-based interface, and TGC (**T**ango based **G**MRT **C**ontrol system), the GAB M&C system firmware on Rabbit (RCM 4300) card is modified to accept new command for setting Reference LO, and Step-size. After validation testing of updated Rabbitfirmware version 1.09, from Mar 3<sup>rd</sup>, 2022 onwards, default observatory values of GABsystem for reference LO, and step-size have been fixed to 105 MHz and 1000 KHz respectively.

Revision	Date	Modification/ Change
Ver 0.9	Mar 30, 2022	Initial Version
Ver 1.0	Apr 04, 2022	Revised Version By team members
Ver 1.1	Apr 06, 2022	Corrected as per the review comments by Backend Group- coordinator (Ajithkumar)

## Modification and Validation Testing of the GAB-LO Control parameters

Version: 1.1 Apr 06, 2022
Authors: *Operation group* - Jitendra Kodilkar, Amol Chavan *Analog group* - Sweta Gupta, Abhijeet Dhende, Ajay Vishwakarma Navnath Shinde, Ajith Kumar

## **1. Introduction:**

The GAB LO system in synthesizer mode was earlier working for default Reference LO, and Step-Size values of 10 MHz and 10 KHz respectively. The *ADF4351 wideband PLL synthesizer with a integrated VCO*<sup>1</sup> used in GAB system allows reference LO settings from 10 to 250 MHz and Step-size (Channel Resolution) from 10 to 1000 KHz. To enable custom settings for Reference LO, and Step-sizes using the Web-based interface and TGC (Tango based GMRT Control system), the GAB M&C system firmware on Rabbit (RCM 4300) card is modified to accept new command for setting Reference LO, and Step-size. At present, considering the GAB hardware limitations, Reference LO and Step-size has to be same for both the Polarisations.

Modifications done in control-monitoring chain from the TGC to rabbit-firmware are summarized as follows:

#### • List of modifications & features added in TGC System:

(i) "set reflo (*<REF\_LO1>*, *<REF\_LO2>*, *<CH\_Sp1>*, *<CH\_Sp2>*)" command added in the TGC system to set the GAB reference LO, and Step-size.

(ii) Warning message: GUI Module written to show warning-message to the Control-room user about hardware change in the GAB system is needed before issuing command to set reference LO.

(iii) **Rejecting invalid LO:** To avoid incorrect input settings of LO-values, constraints based on existing reference LO and step-size values are added for rejecting invalid LO values.

**(iv)** New monitoring parameters are added in the TGC system i.e., values of doubler-bit, Channel spacing, Reference-LO, GAB-LO, and SPI-bit pattern set.

• List of modifications & features added in Rabbit Firmware (jointly done by the GAB and Operation group):

(i) **Reference LO** setting was fixed to either 10 or 105 MHz, this is now changed to set from 10 to 250 MHz possible values for testing.

(ii) **doubler-bit:** Logic for doubler-bit setting is implemented, and command provided to set the doubler-bit of ADF4351 at web browser UI.

(iii) **R-counter:** To avoid bug of offset in LO settings, *R-counter* value of ADF4351 is set equal to input value given for the reference, so that PFD (Phase Frequency Detector) frequency always remains 1 MHz.

(iv) Web-page of the GAB rabbit-card is modified to include monitoring feature for Reference LO, Channel Spacing (Step-size), doubler bit, and SPI pattern generated to set the registers of ADF4351.
(v) LO monitoring: To monitor GAB-LO value set in system against the value given by user, LO value is calculated from parameters which are used to set bit pattern of six registers of ADF4351 using the SPI port.

<sup>1</sup> See Appendix-I for Functional Block diagram of ADF4351, and Appendix-II Register Details of ADF4351

#### • Validation Testing of Revised GAB Firmware:

#### (a) Simulator for ADF4351 on Linux:

To avoid direct firmware changes in the Rabbit-card and testing it using the antenna GAB system, a new simulator tool "**setgabLO**" is developed on Linux machine which uses the same algorithms from Rabbit-card. This tool shows resultant ADF4351 control-parameters for desired LO settings, which are used to generates a LO bit-pattern. Thus, required changes first can be done in the "**setgabLO**" tool, and then resultant control-parameters and LO bit-pattern can be independently verified with a Window's based *ADF435x Shareware software* (developed by Analog devices) application.

#### (b) Validation Testing in Lab, and GMRT observations:

For authentication of the changes done in Rabbit-firmware, Analog group used a Lab test setup consisting GAB MCM PIU, LO Synth PIU, Frequency Counter & Spectrum Analyzer, and measured different LO frequencies with multiple combinations of Reference LO(s) and step-sizes. Also, visibility data was acquired on calibrator sources from band-3 to band-5 (on Feb 23, 2022, and Mar 3, 2022) to ensure that amplitude and phase stability is within a threshold.

# After validation testing of updated Rabbit-firmware version 1.09 is released from Mar 3<sup>rd</sup>, 2022 onwards, default observatory values of GAB-system for reference LO, and step-size have been fixed to 105 MHz and 1 MHz respectively.

In subsequent sections, *section-2* describes modifications carried in firmware and validation testing. *section-3* contains technical details related to algorithms used to generate LO pattern values, because legacy Dynamic-C program on Rabbit-card lacks any kind of document. Therefore, it is important to have a clear understanding of what software does especially when two groups are working collaboratively. Last, **Section-4** gives TGC implementation details as a SOP.

## 2. Rabbit Card Firmware Changes

#### (I) Control and Monitoring:

Although, command to Set reference-LO was available previously, it was allowed only for two values viz. 10 MHz or 105 MHz. Therefore, firmware modified to set Reference LO value ranging from 10 to 250 MHz (only integer values in MHz) with a command to set doubler Bit On or Off. Both these commands are made available on web-based interface of the GAB rabbit-card.

*Figure-1 (a)* depicts Control web-page of Rabbit-card for commands available to users. And Figure-*1 (b)* shows new data variables added on monitoring page of Rabbit-card mainly (i) doubler bit (ii) Step-Size for channel-1, and channel-2, and (iii) SPI Bit pattern generated for setting register 0 to 6 of ADF4351.

'*LO Frequency*' monitoring in **Figure-1 (b)** previously were displaying values which are received to set the LO frequency, i.e., input parameters of command 'set lo <LO1> <LO2>' from user or TGC system.

During testing, it is found that certain resultant ADF4351 register-values deduced by Rabbit firmware module "**Set\_LO()**" may generate different LO than the expected/given (based on set Reference LO, Step-Size, and input gab-LO value asked to set ). Therefore, parameters which are used to set ADF 4351 registers are taken to recalculate the LO, and same value is assigned for monitoring 'LO Frequency' parameter. This ensures the correctness of asked LO frequency to set by user Vs actual generated LO-Frequency by ADF4351.

							1101	1101	1 11101	1100111	19 WII	iuo w					
New MCM Control Wind	low																
IP:192.168.30.33 Antenna: 5	System : Analog Back End RESET						6	4 MON	ITORI	NG CH.	ANNEL	S					
SET 32 Digital Output		01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16
		980 0.000	121 4.536	118 4.552	976 0.021	982 -0.01	122 4.531	976 0.021	980 0.000	979 0.005	1104 -0.65	826 0.813	352 3.316	810 0.898	131 4.483	949 0.164	949 0.164
0000	Submit	17 858	<b>18</b> 830	<b>19</b> 43	<b>20</b> 978	<b>21</b> 978	<b>22</b> 987	<b>23</b> 828	<b>24</b> 355	<b>25</b> 980	<b>26</b> 977	<b>27</b> 651	<b>28</b> 628	<b>29</b> 337	<b>30</b> 818	<b>31</b> 825	<b>32</b> 826
		0.644	0.792	4.948	0.010	0.010	-0.03	0.803	3.300	0.000	0.015	1.737	1.859	3.395	0.855	0.818	0.813
ADF Settings		<b>33</b> 124	<b>34</b> 982	<b>35</b> 984	<b>36</b> 981	<b>37</b> 983	<b>38</b> 117	<b>39</b> 983	<b>40</b> 980	<b>41</b> 980	<b>42</b> 1292	<b>43</b> 828	<b>44</b> 341	<b>45</b> 790	<b>46</b> 128	<b>47</b> 949	<b>48</b> 949
CH1 CH2		4.520	-0.01	-0.02	-0.00	-0.01	4.557	-0.01	0.000	0.000	-1.65	0.803	3.374	1.003	4.499	0.164	0.164
LO Frequency	MHz	<b>49</b> 848	<b>50</b> 832	<b>51</b> 34	<b>52</b> 977	<b>53</b> 984	<b>54</b> 976	<b>55</b> 830	56 343	<b>57</b> 785	<b>58</b> 827	<b>59</b> 826	<b>60</b> 828	<b>61</b> 828	<b>62</b> 828	<b>63</b> 827	<b>64</b> 827
		0.697	0.782	4.995	0.015	-0.02	0.021	0.792	3.364	1.030	0.808	0.813	0.803	0.803	0.803	0.808	0.808
(10 to 250 MHz) 105 105	MHz		_	_	_		_	_	MOM		,	_	_	_		_	_
Step Size (10 to 1000 KHz)         1000         1000	KHz		_	_	_	_	-	-	MCM S	STATUS	)	_	_	_	_	_	_
ON/OFF) 0 Submit		МСМ Т	īme	1	1:09:35		15-03	3-2022		Clock	Frequend	cy 60	) MHz				
		Spectr	um Spre	ader N	Iormal (0-	50MHz)	Norm	al (>50N	1Hz)	Clock	Doubler	0	n				
RFI Test		Digital	Mask	0	110		8226			Clock	Divided I	By 1					
RTI Test																	
Spectrum Spreader Choose SS 🗸								ANALO	G BAC	KEND	STATUS	6					
Frequency Doubler Choose FDB V		LO Fre	quency	1	105.00		1105	.00		LO Re	f Freque	ncy 1	)5.0 MHz	:	105.0	MHz	
Frequency Divider Choose FDV 🗸	Submit	Attenu	ation	1	2.5 dB		15.0	dB		Filter		2			2		
		LPF		1	.00 MHZ		100 M	ИНΖ		Input		R	F		RF		
Network Settings		Source		S	ynthesize	er	Synth	nesizer		Path		м	ixer		Mixer		
			er Volta		5.0 V		-5.0				ing Volta	ages +:			-12.0	V	
IP Address 192.168.30.33				0			0	-					000 KHz		1000		
Server Port 3003	Password	Double								Step S							
Subnet Mask 255.255.0		SPIBit	(0-2)	0	228 8000	0020	0 0011	7C1A	4E42	SPIBit	(3-5)	00	)E1 07F3	0014	4 0124	0058 0	005
Gateway Address 192.168.30.1	Submit							Click H	Here to S	SET Nev	w MCM						
Designed @ Telemetry Lab - GMRT								Design	ied @ Telei	metry Lab	- GMRT						
Element (a) · Construct Web manage of CAD Dalli's and	]		1 1	3.5	•, •	TAT	,		CAR		1 • .	,					

Figure 1 (a) : Control Web-page of GAB Rabbit-card

Figure 1 (b) Monitoring Web-page of GAB Rabbit-card

#### (II) Bug Resolving - Wrong LO value due to fixed R-Counter value:

The legacy *Set LO()* module of GAB firmware was having fixed value of R-Counter equal to 10.

The constant value of R=10 was causing setting of wrong LO frequency value for Reference LO value 105 MHz with step-size of 1 MHz. Figure -2 shows ADF 435X shareware display where 1459.5 MHz incorrect resultant value of RF Out when RF Frequency ('GAB LO Frequency') is given 1460 MHz with Reference LO 105 MHz, Step Size 1000 KHz, and R-Counter=10.

Figure-2: Incorrect GAB-LO 1459.5 MHz with R=10, Reference LO 105 MHz, & Step-Size 1 MHz

Analog Devices ADF435x Software	-	×
File Tools Help		
Select Device and Connection Main Controls Registers Sweep and Hop Other Functions Features		
RF Settings Given GAB-LO Cutput VCO	Register 4	
RF Frequency: 1460 2920 MHz Low Noise/Spur Mode: Low spur mode V A LDP: 10 ns V	VCO Powerdown: Disabled	~
Channel spacing: 1000 2000 kHz Muxout: Testmodes V PD Polarity: Positive V	MTLD: Disabled	$\sim$
Output divider: 2 Double buff: Disabled V Powerdown: Disabled V	Aux Output Select: Divided	$\sim$
Reference Frequency: 105 MHz Charge pump current: 2.50 V CP 3-state: Disabled V	Aux Output Enable: 1. Enabled	~
R counter: 10 + Ref Doubler: Ref /2: LDF: FRAC-N V Counter reset: Disabled V	Aux Output Power: -4 dBm	$\sim$
PFD Frequency: 10.5 MHz Register 3	RF Output Enable: 1. Enabled	$\sim$
Prescaler: 4/5 V Band Select Clock Mode: High V ABP: 3 ns (INT-N) V	RF Output Power: -4 dBm	$\sim$
Charge Cancellation: Enabled V CSR: Disabled V	Band Select Clock	
Feedback signal: Divided v 1459.5 MHz FRAC FRAC FRAC	Auto set Divider: 64	<b>•</b>
INT 0 PFD (MHz) Div RFout (MHz) CLK Div Mode: Resync Enable V Tsync = 48.38095238095	Freq (kHz): 164.06	53
(139 + 2)x 10.5 / 2 = 1459.5 Register 5		
MOD N = 139 LD Pin Mode: Digital Lock Detect V		
Phase adjust: 0. Off V Phase Value: 90 -		
Registers		
0x 458000 0x 2D0011 0x 7C028E42 0x E107F3 0x 14012	4 0x 580005	
	+ UX 360003	Write All Registers
Write R0         Write R1         Write R2         Write R3         Write R4	Write R5	Negisters
and re-plugging the USB cable	in use: ADF4351 PA	NALOG EVICES
no device connected		:

R counter allows the input reference frequency to be divided down to produce the reference clock to the PFD (Phase Frequency Detector). Therefore, after consulting with the GAB personnel, it was decided to keep R-Counter value equal to the Reference LO value (Reference *Frequency* mention in Figure-2). Hence, PFD value now onwards will be always of 1 MHz cycle.

## 2.1 Validation Testing

#### I. Lab Testing:

After the Rabbit-firmware updates, various GAB LO settings with a multiple combination of Reference-LO, Step-size, and doubler-bit On/Off were tried using web-browser interface, and measured it using the Agilent make Frequency counter, and Spectrum Analyzer. Expected values of GAB-LO(s) are observed correctly with Reference LO(s) 10, 105, 86 and 120 MHz and varying

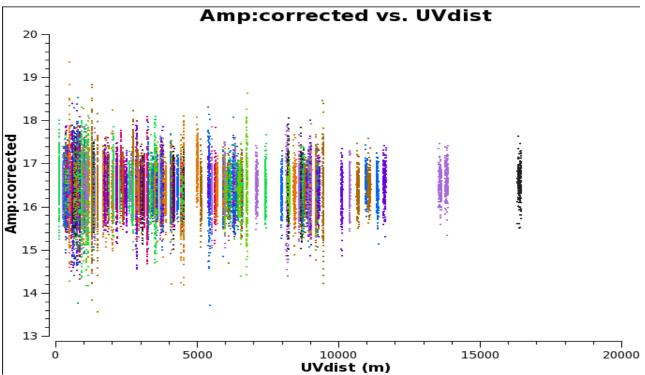
step-sizes (10 KHz to 1000 KHz as an integer values). Please refer the *Web Browser based Lab testing for revised GAB Firmware* by Analog group (**Reference -** *Sweta Gupta*, *Abhijeet Dhende et al*.)<sup>2</sup>.

#### **II. GMRT Observations:**

After successful Lab-testing of the revised GAB-LO firmware working at different reference LO(s) and Step-sizes, firmware is changed for GAB systems in the Receiver-room for all antennas. With a revised firmware, test observations were conducted using calibrator sources at band-3, 4, and 5.

**Figure-3** show cross amplitude Vs UV-distance (in K $\lambda$ ) data taken on 3C48 source at L-band (*Date: Mar 2, 2022, Test Log No – 2531, Reference – Navanath Shinde*, Settings: RF Full Band, GAB LO-1460 MHz, BW 200 MHz). Plot (**3a**), and (**3b**) in Figure-3 show data taken using the Reference LO of 10 MHz and 105 MHz respectively with a 1 MHz Step-size is having stable amplitude. Plot (**3c**) is also depected to show the amplitude Vs UV-distance plot with a Common Reference LO mode of 10 MHz.

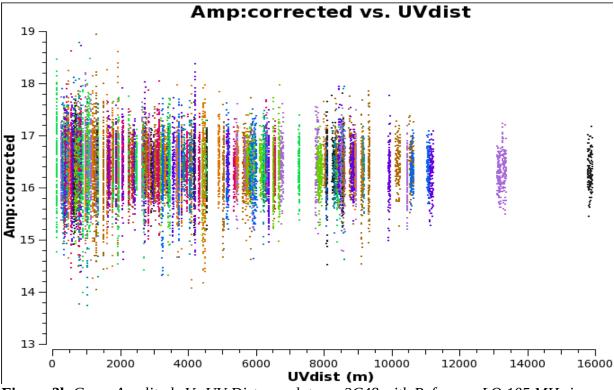
Similarly, amplitude, and phase gain of individual antenna is checked on Feb 23, 2022 using 3C147 source data at Band-3, Band-4, and Band-5. Amplitude, and phases are stable for the data (TestLog 2525, *Reference: Sweta Gupta*).



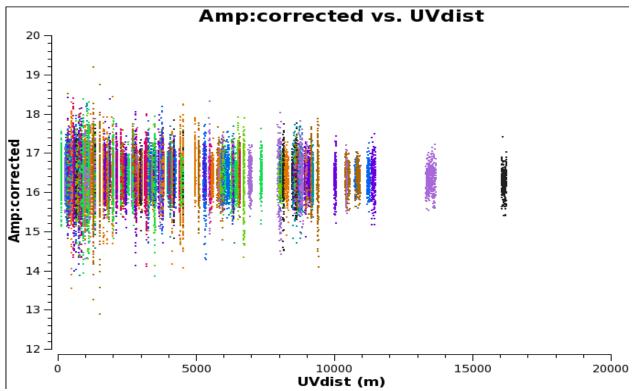
**Figure-3a** Cross-Amplitude Vs UV-Distance data on 3C48 with Reference LO 10 MHz in GAB Synth. Mode at L-Band (Mar 2nd, 2022)

Hence, it can be concluded that based on Lab-tests, and visibility data taken on calibrator sources with a multiple combination of Reference LOs (**i.e.** Ref LO 10, 105 MHz, Channel Resolution 1MHz, and Band 3 to 5), GAB LO in Synthesize mode is working correctly with a revised Rabbit-Firmware.

2 http://iflab/analogbackend/Reports/Web%20Browser%20based%20Lab%20testing%20for %20revised%20GAB%20Firmware.pdf



**Figure-3b** Cross-Amplitude Vs UV-Distance data on 3C48 with Reference LO 105 MHz in GAB Synth. Mode at L-Band (Mar 2nd, 2022)



**Figure-3c** Cross-Amplitude Vs UV-Distance data on 3C48 with Common LO mode at L-Band (Mar 2nd, 2022)

## 3. ADF4351 Set LO Module

**ADF4351** is a wide-band synthesizer with integrated VCO that allows implementation of fractional-N or integer-N phase-locked loop (PLL) frequency synthesizers when used with an external loop filter, and external reference frequency. The ADF4351 has an integrated voltage controlled oscillator (VCO) with a fundamental output frequency ranging from 2200 MHz to 4400 MHz In addition, divide-by-1/-2/-4/-8/-16/-32/-64 circuits allow the user to generate RF output frequencies as low as 35 MHz<sup>3</sup>.

To set the LO for GAB system in synthesizer mode, Rabbit-card sends Control-bit pattern to the ADF4351 using the SPI port. The **Set\_LO\_Pattern()** Module is used for this purpose in firmware. Till now, technical note for this module was not available to understand such as which variable is considered for what, and rationale to assign particular default value (for example, R was fixed to 10, D=T=0). Therefore, it is necessary that control-logic details must be understood, and agreed upon it, especially when two teams from software and hardware groups are involved in the development. For these purposes, a simulator software plays a key role in validation of actual software which can be again reverified for correctness using the external tool such as Windows b*ased 435X Shareware* application.

The **'setgabLo'** simulator is written in C language which prints the ADF4351 control-parameters along with the register Bits to be send using SPI port to ADF4351. The control parameters are responsible to generate user specified GAB-LO, and generated Hex-words for six registers that can be used to diagnosis whether changes done in algorithm is working correctly or not.

*Appendix-I* show the functional block diagram, and *Appendix-II* show ADF4351 control parameters values used in six register which is used to generate the desire LO frequency in synthesizer mode.

#### (i) RF OUT:

The **INT, FRAC**, and **MOD** values, in conjunction with the **R-counter**, make it possible to generate Output Frequencies **RF\_OUT** that are spaced by fractions of the **PFD** frequency.

The RF VCO frequency (RF OUT) equation is

 $RF OUT = f_{PFD} \times (INT + (FRAC/MOD)) \dots (1)$ 

The RF N divider allows a division ratio in the PLL feedback path. The division ratio is determined by the INT, FRAC, and MOD values, which build up this divider.

In above equation (1) and (2), variables used are as follows:

- **RF OUT** is the Output Frequency range: 35 MHz to 4400 MHz
- **INT** is the preset divide ratio of the binary 16-bit counter (23 to 65,535 for the 4/5 prescaler; 75 to 65,535 for the 8/9 prescaler).

Int = (unsigned int) rf<sub>OUT</sub> .....(2a)

<sup>3</sup> Analog Devices Data sheet ADF 4351 – Wideband Synthesizer with Integrated VCO (https://www.analog.com/media/en/technical-documentation/data-sheets/ADF4351.pdf)

• **FRAC** is the numerator of the fractional division (0 to MOD – 1).

 $FRAC = (RF_{OUT} - INT) * MOD \qquad (2b)$ 

• *MOD* is the preset fractional modulus (2 to 4095) counter.

 $MOD = (unsinged int) ( (f_{PFD} / Channel-Spacing) * 1000 ) \dots (2c)$ 

Where Channel Spacing is a step-size, default value is 1 MHz. Note that as per the data sheet, MOD value is minimum kept to 2.

#### (ii) Phase Frequency Detector ( F<sub>PFD</sub>) :

PFD takes inputs from the R-counter & N-counter, and produces an output proportional to the Phase and Frequency difference between them.

The PFD frequency ( $f_{PFD}$ ) equation is

 $f_{PFD} = REF_{IN} \times [(1 + D)/(R \times (1 + T))]$  .....(3)

#### Variables used in equation (3) are as follows:

- **REF**<sub>IN</sub> is the Reference input frequency, default value is 105 MHz, allowed value is 10 to 250 MHz
- **D** is the  $\text{REF}_{IN}$  doubler bit (0 or 1), default value is 0
- **R** is the preset divide ratio of the binary 10-bit programmable Reference counter (1 to 1023).

At present R = REFin

- **T** is the REF<sub>IN</sub> divide-by-2-bit (0 or 1) T = 0.
- Note that rounding logic is applied for **MOD**, **FRAC** values if the last decimal place is equal to greater than 9.

## 4. Changes in Tango based GMRT Control System:

#### I. 'Set Reference LO' Command:

GAB-LMC, and CMC databases modified to add set reference LO command along with the Step-Size value for POL1 and POL2 of antenna. The new command at CMC and GAB-LMC is as follows:

#### set reflo (<REF\_LO1>, <REF\_LO2>, <CH\_Sp1>, <CH\_Sp2>)

Where, REF\_*LO1*, *REF*\_*LO2* - is reference LO to set from 10 to 250 MHz, default value is 105 MHz. And CH\_sp1, CH\_Sp2 is a step-size or Channel-spacing in KHz from 10 to 1000 KHz , with Default value is 1000 KHz.

Above command in the GUI is also available with alias SETREFLO. In Scripting interface, this command is available as:

set\_gab\_reflo(<antenna-name or subarray\_number>,<ref lo1>,<ref lo2>,<ch\_sp1>,<ch\_sp2>)

**II. Warning Message:** A configurable GUI Module *tgcWarn.py* in python is written, where warning message can be configured and displayed at the CMC GUI if command being issued needs some preparatory setup, or consequences of command after issuing it shall be noticed by the Control-room user (For example, Servo Park command may give warning about check the stow-locked status, as stowing of some antenna may give problem). This warning message is up for maximum 10 seconds or User can cancel or forward the command by clicking '**OK**' button immediately. In case, user doesn't respond for *10 second*, command is automatically issued.

**Figure 4(a)** shows that warning message '*Ensure Hardware changes for GAB Reference LO (Other than default 105 MHz)*' is configured for 'set reflo' (Set reference LO command) to inform user that changes in GAB Reference LO settings required GAB-hardware setup changes in the Receiverroom.

**III. Rejecting invalid LO:** GAB IO Server-code in CPP (Subsystem.cpp) is modified to validate the GAB-LO value given by user based on the Step-Size, and Reference LO. The setgabLO() simulator module used here to calculate correct LO by using the ADF4351 Control-parameters (*INT*, *FRAC*, *MOD etc. see equation-1 in section-3*), and if GAB-LO value given by the user is not same that of resultant calculate GAB-LO value, then command is rejected.

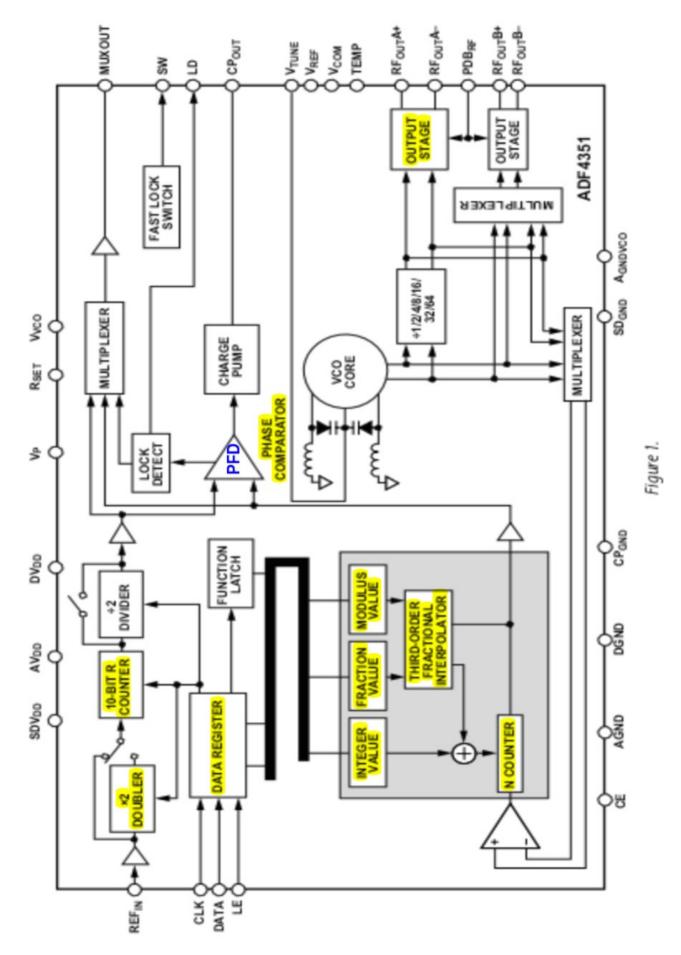
**Figure 4(b)** shows that GAB-LO 555590 KHz is not allowed when the Step-Size is set to 1000 KHz.

Operator@cmsserver					- 🗆 🗵
ST Date: 15-03-2022 IST: 12:01:17 LST: 22:58:52 UT	: 06:31:17 Ser	ver Status : Server Up State :	Manual Mode M&C Status :	ОК	Operator Test_Operator
Operator5_Array: 4 Backend Status Subtask C	Owner Ob:	serving Prog : <file name=""></file>	GMRT Alarms	Alarm	Reports
Mode: Manual Mode GSB 99.99 NA Opera GWB 99.99 NA Opera	Comman	d : C03 -> GAB -> SETREFLO	(on cmsserver) X	ure Alarm	Subarrays
<u>V</u> iew Control <u>M</u> onitor <u>U</u> tilities <u>R</u> ecent		meter Value valid/Range Value			
CL Subsystem Antenna LM	lor1 105	10.0 to 150.0	shboa	rd -> AGN Status ->AGN5 -> Status	
FECB FPS OFCSNT SIGCON SERVO GAB LMCSys	lor2 105	10.0 to 150.0		AGN5 IST: 12:01:17 Introspect	Filter
Antennae	chsp1 10	10 to 1000			
X C03	chsp2 10	10 to 1000		OK OK NOT OK	
15-03-2022 12:00:59 : [SET REFLO] Command Executed success Frequently used commands SETREFLO SET ATTN SET DOMON TIME SET FILRF SET GAB , SET LO SET LPF SET MAINTENANCE SET MIX SET SPARE SET SYNTH SET32DIG SET64DIG SE	15-03-2022 12:00:4	GAB (on cmsserver) set reflo : Ensure Hardware for <u>Cance</u> 14 :Valid command. Command fo lear			
ctivity Messages :	Detailed	Resp. Filter History		Alexa True	Filter History 🔯
15-03-2022 11:593-11 : [Status] [CMC] Server up 15-03-2022 11:20:53 : [Command] [AGNS] [C03] [GAB] [SET REFLO] command re 15-03-2022 12:00:59 : [Response] [AGNS] [SET REFLO] Command Executed succ	ceived essfully		Alarm Name	Alarm Type Al	arm Description Date/Time

**Figure-4 (a)** 'set reflo' or SETREFLO command in TGC using the GUI interface

	Central N	Aonitoring & Control : (	Operator Station 5 (on cmsserver)	
Operator@cmsserver				
IST Date: 15-03-2022 IST: 12:02:55 LST: 23:00:30 UT	C: 06:32:55 Server Status : S	Server Up State : Manua	al Mode M&C Status : OK	Doperation Operation
Operations_Array: 4	Owner Observing Prog :	<file name=""></file>	GMRT Alarms Vind Alarm	
Mode:         Manual Mode         GSB         99.99         NA         Operative           GWB         99.99         NA         Operative	Command : C03 -> GA	.B -> SET GAB LO (on cr	msserver) × perature Alarm	
<u>View Control Monitor Utilities Recent</u>	Parameter Value	valid/Range Value		
Ot Subsystem Antenna LM	Lo Freq Ch 1 555590	100000 to 1500000	shboard -> AGN Status ->AG	15 -> Status
FECB FPS OFCSNT SIGCON SERVO GAB LMCSys	Lo Freq Ch 2 555500	100000 to 1500000	AGN5 IST: 12:02:55	Introspect Filter
Antennae		Ŀ	List of arguments for selected command	
X C03			GSB[R] GW	B(R) GAB(R)
Frequently used commands SET GAB LO SETREFLO SET ATTN SET DOMON TIME SET FILRF SET GAB, SET LO SET LPF SET MAINTENANCE SET MIX SET SPARE SET SYNTH SET32DIG SET64DIG SI Activity Messages :	Reset Clear	Exec	ute Cancel	Filt
15-03-2022 12:01:21 : [Command] [AGN5] [C03] [GAB] [SET REFLO] command n	eceived			1 Type Alarm Description
15-03-2022 12:01:24: [Response] [ACHS] [STT REFLO] Command Executed suc 15-03-2022 12:01:41: [Command] [ACHS] [STG IABL6] [STG ABL0] command 15-03-2022 12:01:45: [Response] [ACHS] [STG ABL0] Command Executed suc 15-03-2022 12:01:57: [Command] [ACHS] [STG IABL0] Command Executed suc 15-03-2022 12:02:01: [Response] [ACHS] [ST GABL0] Command Executed suc 15-03-2022 12:02:21: [Command] [ACHS] [STG IABL0] Command Executed suc 15-03-2022 12:02:21: [Command] [ACHS] [STG IABL0] Command Executed suc 15-03-2022 12:02:21: [Command] [ACHS] [STG IABL0] Command Executed suc 15-03-2022 12:02:28: [Command] [ACHS] [CG] [ACHS] [STG REFLO] Command 15-03-2022 12:02:28: [Command] [ACHS] [CG] [ACHS] [STG FAELO] (command 15-03-2022 12:02:28: [Command] [ACHS] [CG] [ACHS] [STG FAELO] [command] [ACHS] [CG] [ACHS] [STG FAELO] [CG] [ACHS] [STG FAELO] [command] [ACHS] [CG] [ACHS] [STG FAELO] [command] [ACHS] [CG] [ACHS] [STG FAELO] [command] [ACHS] [CG] [CHA _CG] [STG FAELO] [command] [ACHS] [CG] [CHA _CG] [STG FAELO] [command] [SG FAELO] [cG] [CG] [CGA _CG] [STG FAELO] [cG] [STG FAELO] [cG] [SG FAELO] [cG] [STG FAELO] [cG] [S	received ccessfully eceived ccessfully eceived ccessfully received			

Figure-4 (b) Invalid LO message when RefLO 105 MHz, and Step-size 1000 KHz



#### APPENDIX-I: ADF4351 Functional Block Diagram

# ADF4351

# **Data Sheet**

0000-003

# **REGISTER MAPS**

					(C.)) (C									R	EGISTE	R 0															
RESERVED					8	16-BIT		<b>IT</b> ier va	LUE (II	νπ)									1	2-BIT F	RACTI			E (FR/	AC)				0	ONTRO	n.
DB31	0630	D629	0628	DB27	DB26	DB25	D824	D823	0622	D821	DB20	DB19	0818	0817	DB16	D815	DB14	DB13	DB12	DB11	DB10	DE9	DB8	DB7	DB6	DB5	DB4	DB3	DB2	DB1	DB0
0	N16	N15	N14	N13	N12	N11	N10	N9	N8	N7	Nő	N5	N4	N3	N2	NI	F12	F11	F10	F9	F8	F7	F6	F5	F4	F3	F2	F1	C3(0)	C2(0)	C1(0)

-			_	_																											
,	ESERV	/ED	PHASE ADJUST	PRESCALER				12-B/	T PHAS	E VAL	UE (PH	ASE)	t	XBR <sup>1</sup>						12-8/T	MODU			(MOC	9	DBR	1		o	ONTRO	NL.
D831	DB30	DB29	D628	DB27	0826	DB25	DB24	DB23	D822	D821	DB20	DB19	DB18	DB17	DB16	DB15	DB14	D813	DB12	D811	DB10	DB9	DB8	D87	DB6	DB5	DB4	DB3	DB2	D81	DBD
0	0	0	PH1	PR1	P12	P11	P10	P9	P8	P7	P6	P5	P4	P3	P2	P1	M12	M11	M10	M9	MB	M7	MG	MS	M4	мз	MZ	M1	C3(0)	CS(0)	C1(1)

														R	EGISTE	IR 2															
RESERVED	LOW	DW E AND SPUR DES		iuxou	T	REFERENCE DOUBLER DBR	RDIV2 DBR <sup>1</sup>		REF_IN 10-BIT R COUNTER DBR <sup>1</sup>							R1		DOUBLE		CHARG PUMP CURREI SETTIN	NT	BR1	LDF	LDP	PD	POWER-DOWN	CP THREE- STATE	COUNTER RESET	c	ONTRO	JL JL
D831	D630	DB29	D628	DB27	DB26		DB24	DB23	DB22	DB21	DB20	DB19	DB18	DB17	DB16	DB15	DB14	DB13	DB12	DB11	DB10	DB9	DB8	DB7	DB6	DB5	DB4	DB3	DB2	D81	DB0
0	L2	ы	M3	M2	M1	RD2	RD1	R10	R9	R8	R7	R6	RS	R4	R3	R2	R1	D1	CP4	CP3	CP2	CP1	U6	U5	U4	U3	U2	U1	C3(0)	C2(1)	C1(0)

								BSC	M					R	GISTE	R 3															
$\left[ \right]$		,	RESER	VED				BAND SELECT CLOCK MODE	ABP	CHARGE	RESE	RVED	CSR	RESERVED	D	LK IV DDE				12-	BIT CL	оск г	NVIDE	R VAL	UE				c	ONTRO	DL.
D831	DB30	DB29	DB28	DB27	DB26	DB25	DB24	D623	DB22	DB21	DB20	D619	DB18	DB17	DB16	DB15	DB14	DB13	DB12	DB11	DB10	DB9	DB8	DB7	DB6	DB5	DB4	DB3	DB2	DB1	DB0
0	0	0	0	0	0	0	0	F4	F3	F2	0	0	F1	0	C2	C1	D12	D11	D10	D9	DB	D7	D6	D5	D4	D3	D2	D1	C3(0)	C2(1)	C1(1)

_								c	utp	utdiv	vide	r in	dex		REGIST	ER 4					_	_				_					
			RESER	IVED				FEEDBACK		DBB <sup>2</sup> F DIVID ELECT		8-8	IT BAN	ID SEL	ECT CL	.оск с	DIVIDE	R VALU	E	VCO POWER- DOWN	MILLD	AUX OUTPUT SELECT	AUX OUTPUT ENABLE			RF OUTPUT ENABLE	OUT		C	ONTRO	ж
D831	D630	D829	D628	DB27	DB26	DB25	D624	DB23	0822	D821	DB20	DB19	D818	DB17	DB16	0815	DB14	DB13	DB12	DB11	DB10	DB9	DB8	DB7	DB6	DB5	DB4	DB3	DB2	D81	DBC
0	0	0	0	0	0	0	0	D13	D12	D11	D10	858	857	856	855	854	853	BS2	851	D9	DB	D7	DG	D5	D4	D3	DZ	D1	C3(1)	C2(0)	C1(

REGISTER 5 0X00580005

$ \subset $																															
			RESE	RVED				LD	PIN	RESERVED	RESE	RVED						RESER	VED											ONTRO	ЯL
DB31	DB30	DB29	DB28	DB27	DB26	DB25	DB24	DB23	D822	DB21	DB20	D819	DB18	DB17	DB16	DB15	DB14	DB13	DB12	DB11	DB10	DB9	DB8	DB7	DB6	DB5	DB4	DB3	DB2	DB1	DB0
0	0	0	0	0	0	0	0	D15	D14	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	C3(1)	C2(0)	C1(1)

1DBR = DOUBLE-BUFFERED REGISTER—BUFFERED BY THE WRITE TO REGISTER 0. 2DBB = DOUBLE-BUFFERED BITS—BUFFERED BY THE WRITE TO REGISTER 0, IF AND ONLY IF DB13 OF REGISTER 2 IS HIGH.

Figure 23. Register Summary

#### REGISTER 1

#	ADF4351 Parameter	Register	Data Bit	Range	Remark
1	INT	0	30:15	INT Minimum 23 for the 4/5 <b>prescalar</b> , and 75 for 8/9 <b>prescalar</b> Max – 65,535	The INT value is used in <b>Equation 1</b> (see the INT, FRAC, MOD, and R Counter Relationship section). INT is integer part of Rfout (i.e., GAB LO Frequency entered by user- Range 35 MHz to 4400 MHz). <i>INT</i> = (unsigned int) RF <sub>OUT</sub>
2	FRAC	0	14:03	0 to MOD - 1	FRAC set the Numerator of fraction that is input to the $\Sigma$ - $\Delta$ modulator. This fraction, along with the INT value, specifies the new frequency channel that the synthesizer locks to, as shown in the RF Synthesizer, see <b>Equation 1</b> . <b>FRAC = (RF</b> <sub>OUT</sub> – <b>INT) * MOD</b>
3	MOD	1	14:03	2 to 4095	The choice of modulus depends on the reference LO signal (REF IN) available, and Channel Resolution required at the <b>RF</b> <sub>OUT</sub> , See <b>equation (2c)</b> <i>MOD</i> = ( <i>unsinged int</i> ) ( ( $f_{PFD}$ / <i>Channel-Spacing</i> ) * 1000 ) Where, Channel Spacing is a step-size, default value is 1 MHz. Note that, 1000 is multiplied to convert Reference LO from MHz to Khz.
4	PreScalar	1	27	0 or 1	The dual-modulus prescaler (P/P + 1), along with the INT, FRAC, and MOD values, determines the overall division ratio from the VCO output to the PFD input. Prescalar is 1 if RFOUT is $>$ 3.6 Ghz, otherwise 0.
5	REFin	2	23:14	1 to 1023	Reference LO (REFin) allow from 10 to 250 MHz, <b>REFin_hex = (unsigned int) REFin</b> The 10-bit R-counter allows the input reference frequency (REF IN) to be divided down to produce the reference clock to the PFD. <b>R-Counter, R = REF_IN</b>
6	Reference Doubler (D)	2	25	0 or 1	<ul> <li>(i) D= 0: (a) Disables the doubler, and feeds REFin signal directly into the 10bit R-Counter.</li> <li>(b) REF IN falling edge is the active edge at the PFD input to the fractional synthesizer. (c) The phase noise is insensitive to the REF IN duty cycle in the low noise mode and when the doubler is disabled.</li> </ul>
					INT = (unsigned int) Rfout

# Table – Register-Map values set setgabLO Simulator or Set\_LO\_Pattern() Rabbit-card Dynamic-C Module

					<ul> <li>(ii) D = 1: (a) Multiplies the REFin frequency by a factor of 2 before feeding into the 10-bit R counter. (b) Both the rising and falling edges of REF IN become active edges at the PFD input. (c) When the doubler is enabled and the low spur mode is selected, the in-band phase noise performance is sensitive to the REF IN duty cycle. The phase noise degradation can be as much as 5 dB for REF IN duty cycles outside a 45% to 55% range.</li> <li><i>INT = (unsigned int) Rfout / 2</i></li> </ul>
7	BSCM	3	23	0 or 1	Band-Select Clock Mode: Default value is 1. Setting the DB23 bit to 1 selects a <u>faster logic</u> sequence of band selection, which is suitable for high PFD frequencies and is necessary for fast lock applications. Setting the DB23 bit to 0 is recommended for low PFD (<125 kHz) values
8	ABP	3	22	0 or 1	<ul> <li>The PFD includes a programmable delay element that sets the width of the antibacklash pulse (ABP). This pulse ensures that there is no dead zone in the PFD transfer function.</li> <li>(i) ABP=0, the ABP width is programmed to 6 ns, the recommended value for fractional-N (ii) ABP =1, the ABP width is programmed to 3 ns, the recommended value for integer-N</li> </ul>
9	Charge cancel	3	21	0 or 1	Setting <i>charge cancel</i> bit to 1 enables charge pump charge cancel action. This has the effect of reducing PFD spurs in integer-N mode. <u>In fractional-N mode, this bit should be set to 0.</u>
10	RF Divider or outputdivider_index	4	22-20	0 to 6	<pre>select the value of the RF output divider, based on RFout (or GAB-LO value): Rfout &lt; 2200? outputdivider_index = 1; Rfout &lt; 1100? outputdivider_index = 2; Rfout &lt; 550 ? outputdivider_index = 3; Rfout &lt; 275? outputdivider_index = 4; Rfout &lt; 137.5 ? outputdivider_index = 5; Rfout &lt; 68.75? outputdivider_index = 6; Just for information - The DB23 bit selects the feedback from the VCO output to the N counter. When this bit is set to 1, the signal is taken directly from the VCO. When this bit is set to 0, the signal is taken from the output of the output dividers. The dividers enable coverage of the wide frequency band (34.375 MHz to 4.4 GHz). When the dividers are enabled and the feedback signal is taken from the output, the RF output signals of two separately configured PLLs are in phase.</pre>

**Annexure-I** *GAB LO characterisation for revised Firmware using TGC* is attached to the Next page.

## **Annexure-I**

# GAB LO characterisation for revised Firmware using TGC

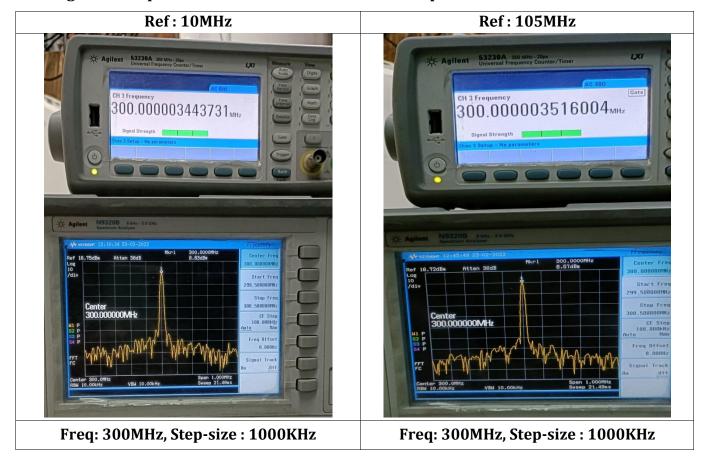
---AMV/ATD/SGA/JPK

#### **Objective:**

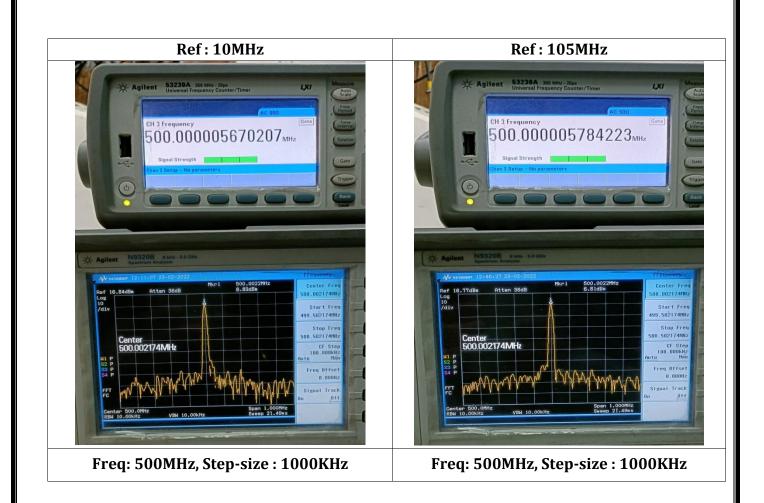
The existing GAB firmware is being revised to provide **default LO reference 105MHz with 1000KHz Step-size**. The revised firmware supports custom LO reference range from **10MHz to 250MHz** with step size ranging **10KHz to 1000KHz**. A separate command is being added in TGC to set any Reference LO and Step-size in the range mentioned above.

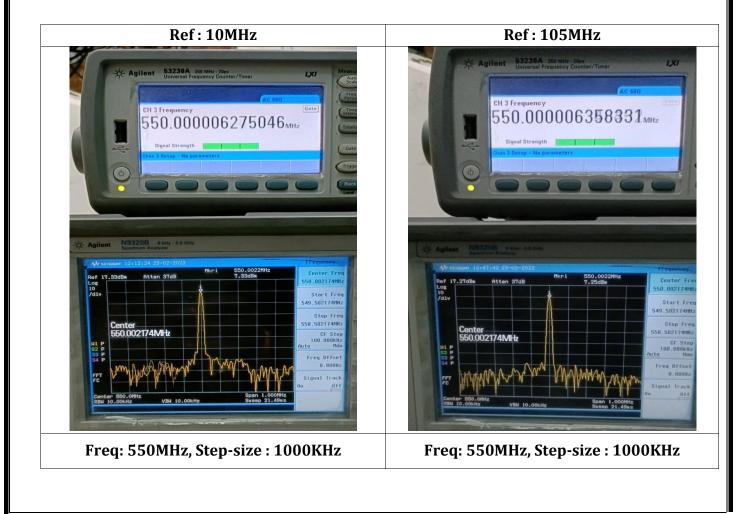
Various combination of GAB-LO using 10MHz and 105MHz reference frequency and varying stepsize has been measured using Agilent make Universal Frequency Counter and Spectrum Analyzer.

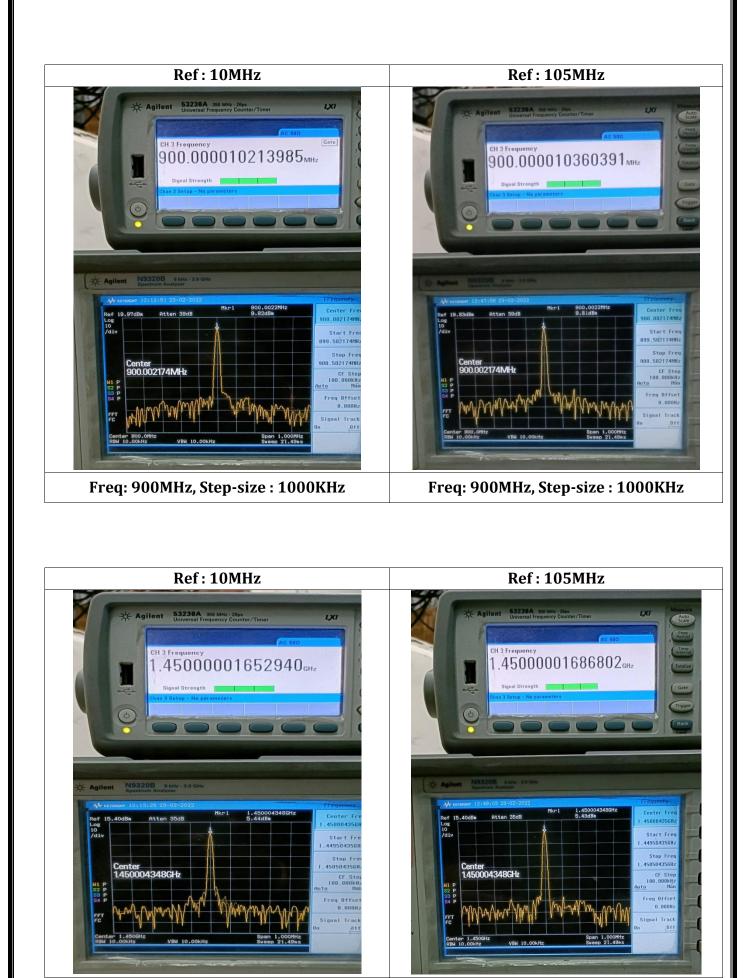
• Below are the snapshots of the measured GAB-LO using Frequency counter and Spectrum Analyzer.



#### **Integer LO Frequencies measurement @ 1000KHz Step-size:**

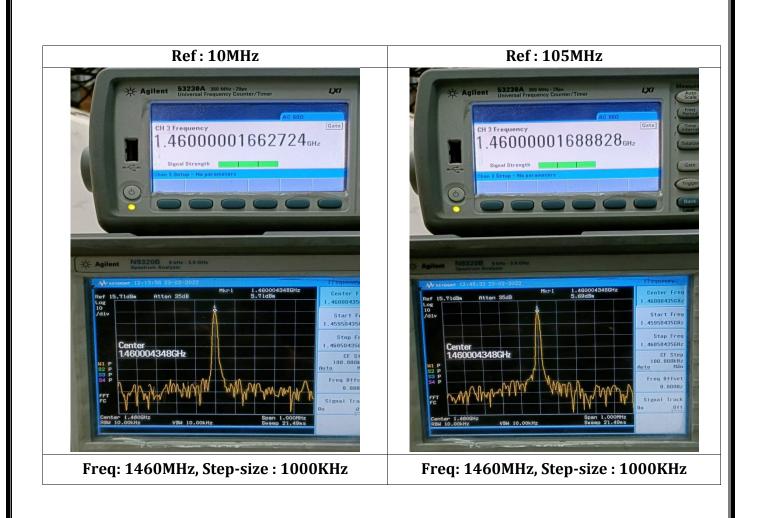


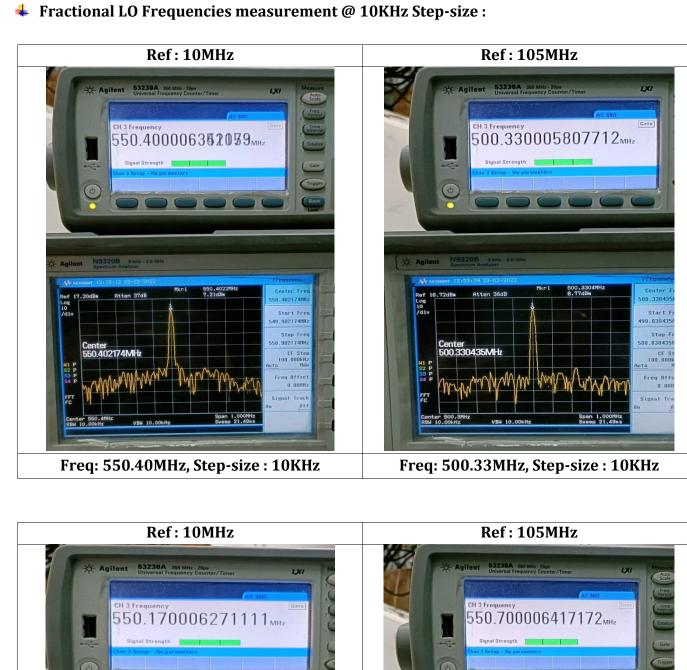


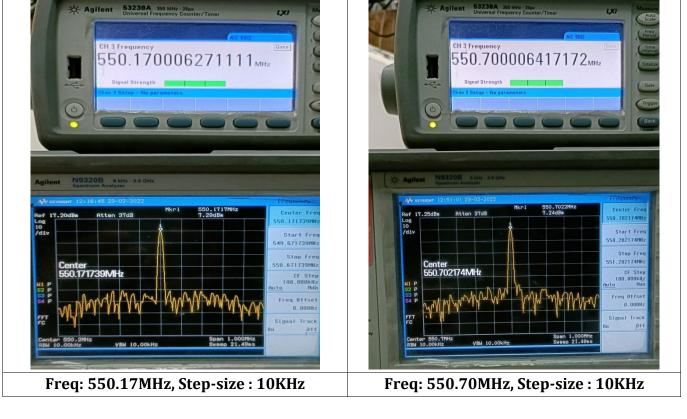


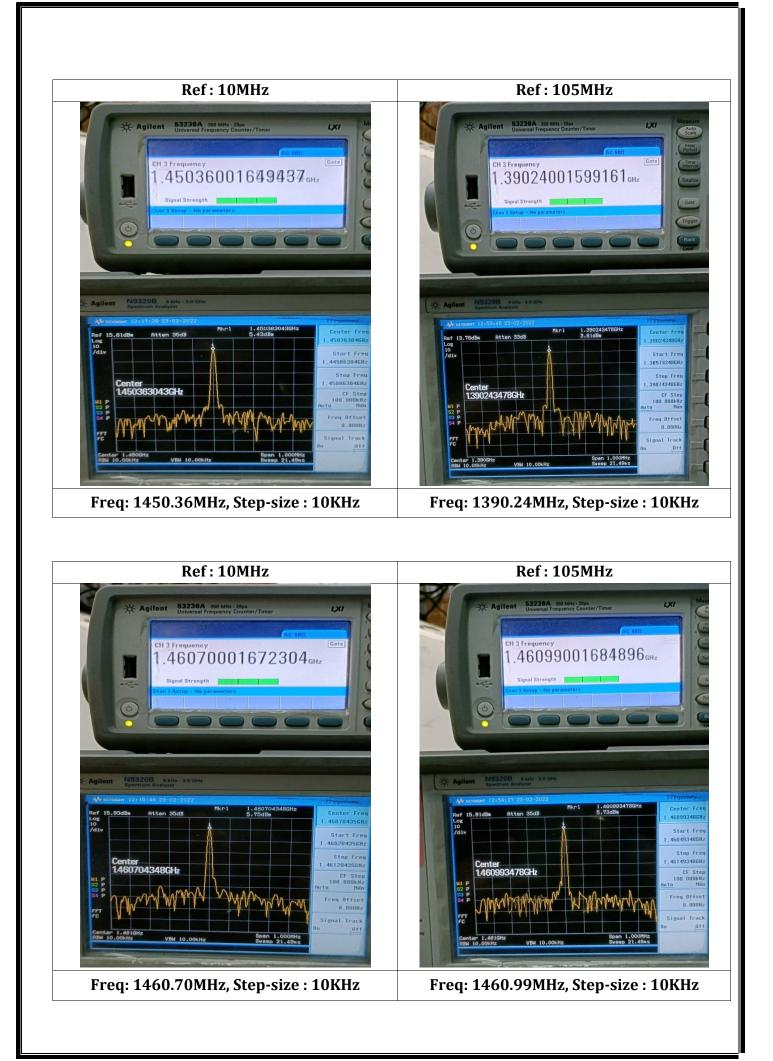
Freq: 1450MHz, Step-size : 1000KHz

Freq: 1450MHz, Step-size : 1000KHz









- CONCLUSION:
- (I) For all combinations of Step-size, and reference LO mentioned above, different set GAB-LO(s) and the measured LO frequencies are same.
- (II) Using the TGC, input GAB-LO(s) asked to set with a resolution of less than 1000KHz are not allowed, as the default Step-size is 1000KHz.