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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 Rabbit-firmware version 1.09, from Mar 3rd, 2022 onwards, default observatory values of GAB-system 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

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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***[1] 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. 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.

1 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 3rd, 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.

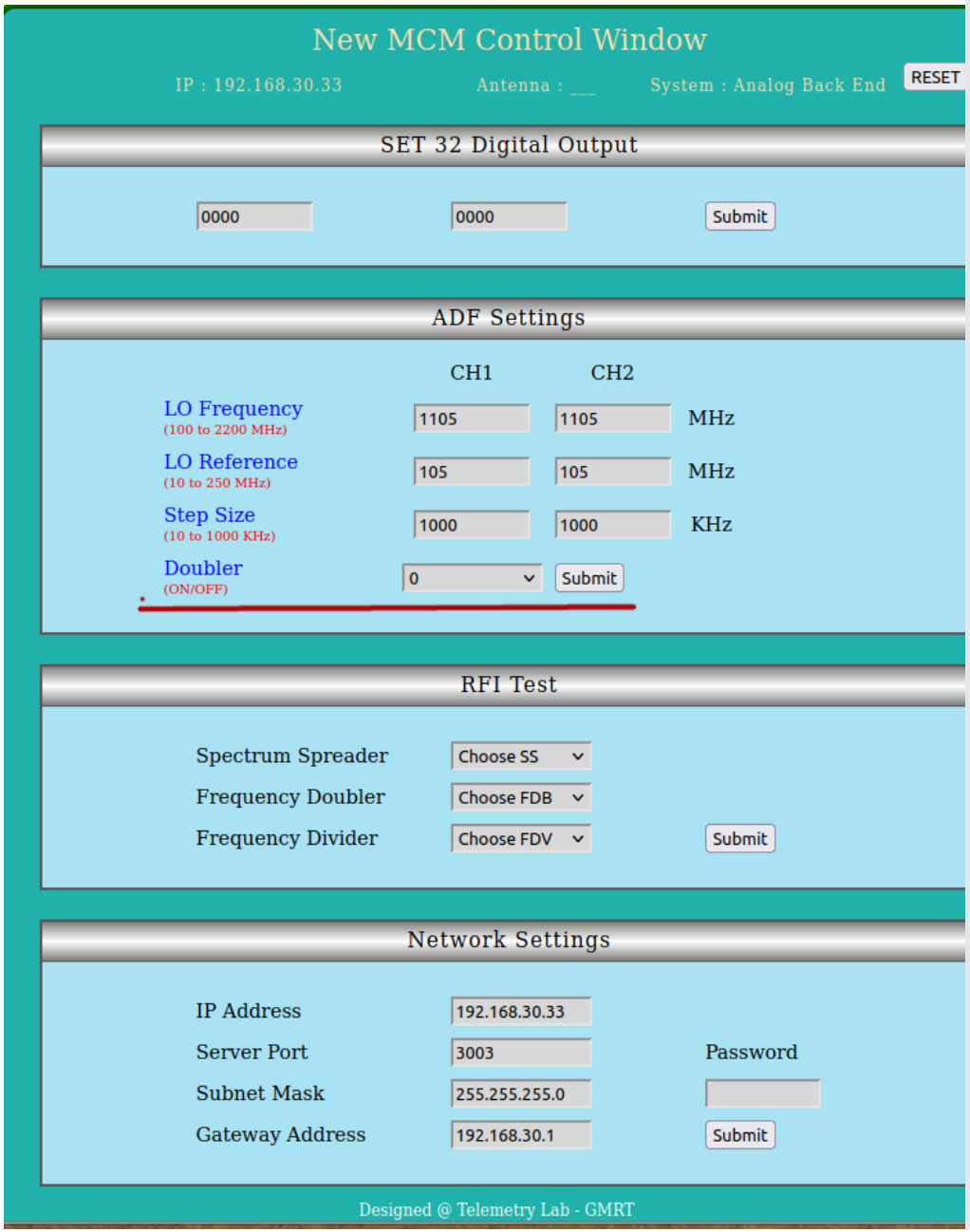


Figure 1 (a) : Control Web-page of GAB Rabbit-card

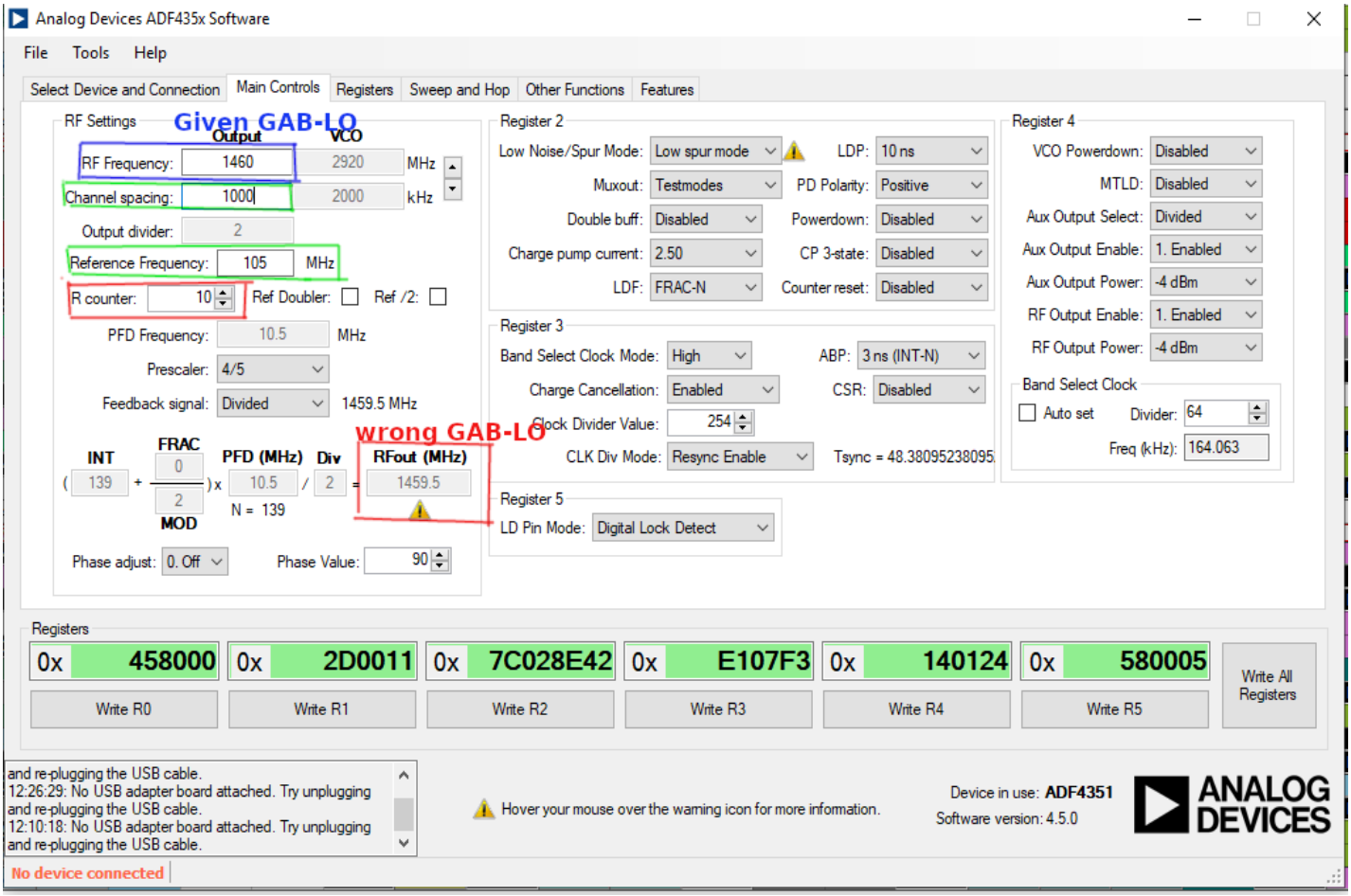
Figure 1 (b) Monitoring Web-page of GAB Rabbit-card

(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



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*.)**[2].

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 Kλ) 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***).

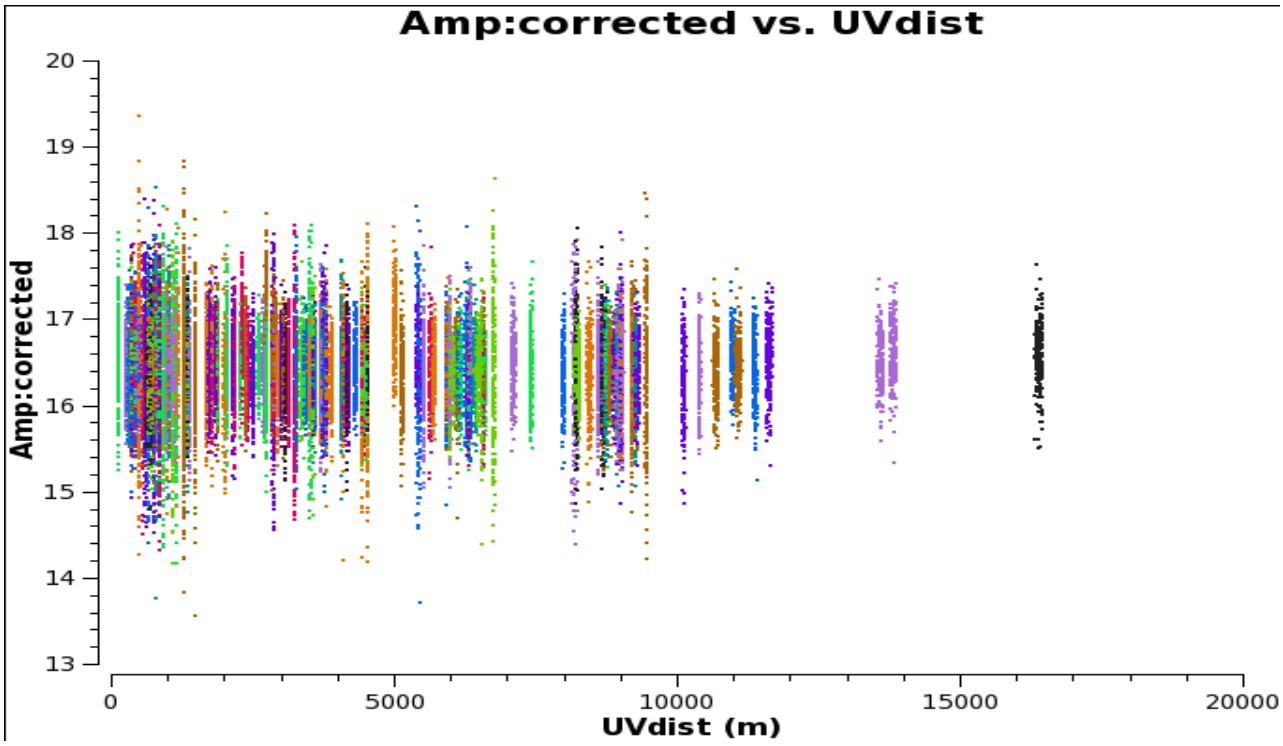


Figure-3a *Cross-Amplitude Vs UV-Distance data on 3C48 with Reference LO 10 MHz in GAB Synth. Mode at L-Band (Mar 2nd, 2022)*

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.

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

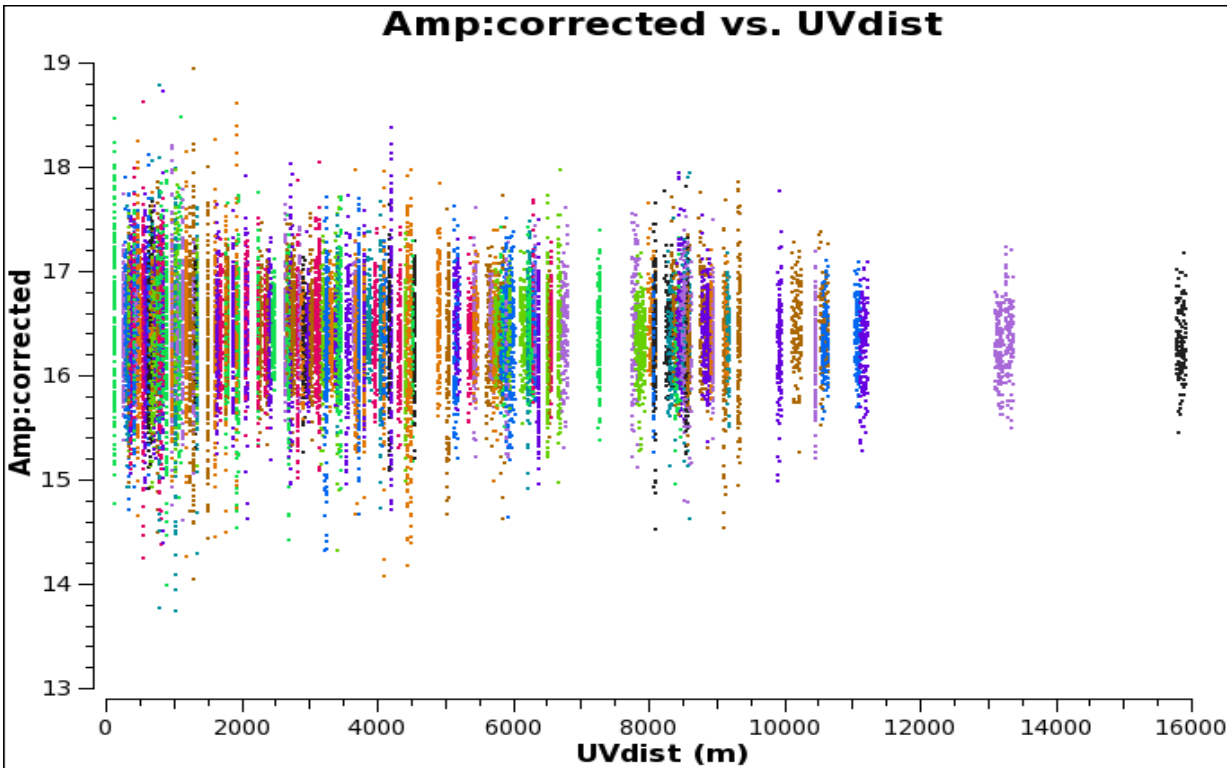


Figure-3b *Cross-Amplitude Vs UV-Distance data on 3C48 with Reference LO 105 MHz in GAB Synth. Mode at L-Band (Mar 2nd, 2022)*

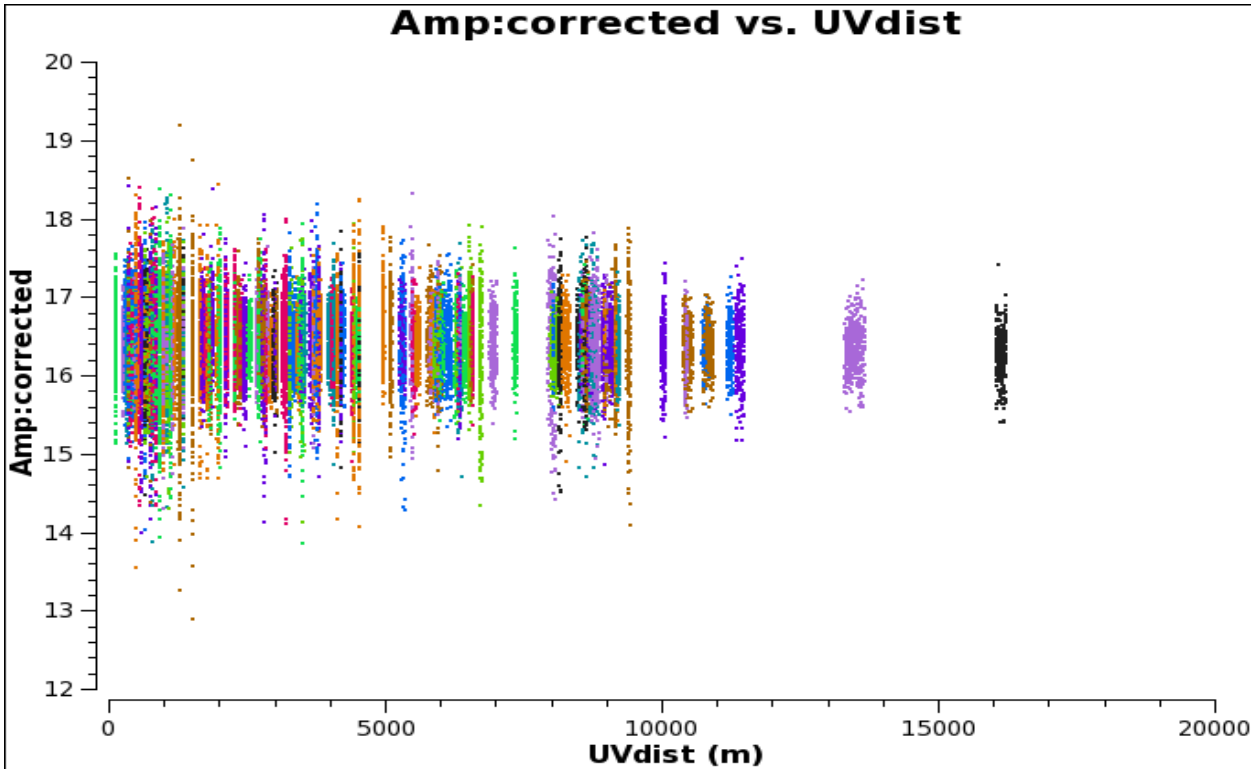


Figure-3c *Cross-Amplitude Vs UV-Distance data on 3C48 with Common LO mode at L-Band (Mar 2nd, 2022)*

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[3].

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

$$\textbf{RF OUT} = f_{PFD} \times (\textbf{INT} + (\textbf{FRAC}/\textbf{MOD})) \quad \text{..... (1)}$$

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.

$$N = INT + FRAC/MOD \quad \text{..... (2)}$$

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).*

$$Int = (unsigned\ int)\ rf_{OUT} \quad \text{.....(2a)}$$

3 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).*

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

- ***MOD i**s the preset fractional modulus (2 to 4095) counter.*

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

  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_{PFD}) :

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

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

Variables used in equation (3) are as follows:

- **REF_{IN}** is the Reference input frequency, default value is 105 MHz, allowed value is 10 to 250 MHz
- **D** is the 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 i**s the REF_{IN} 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 Receiver-room.

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.

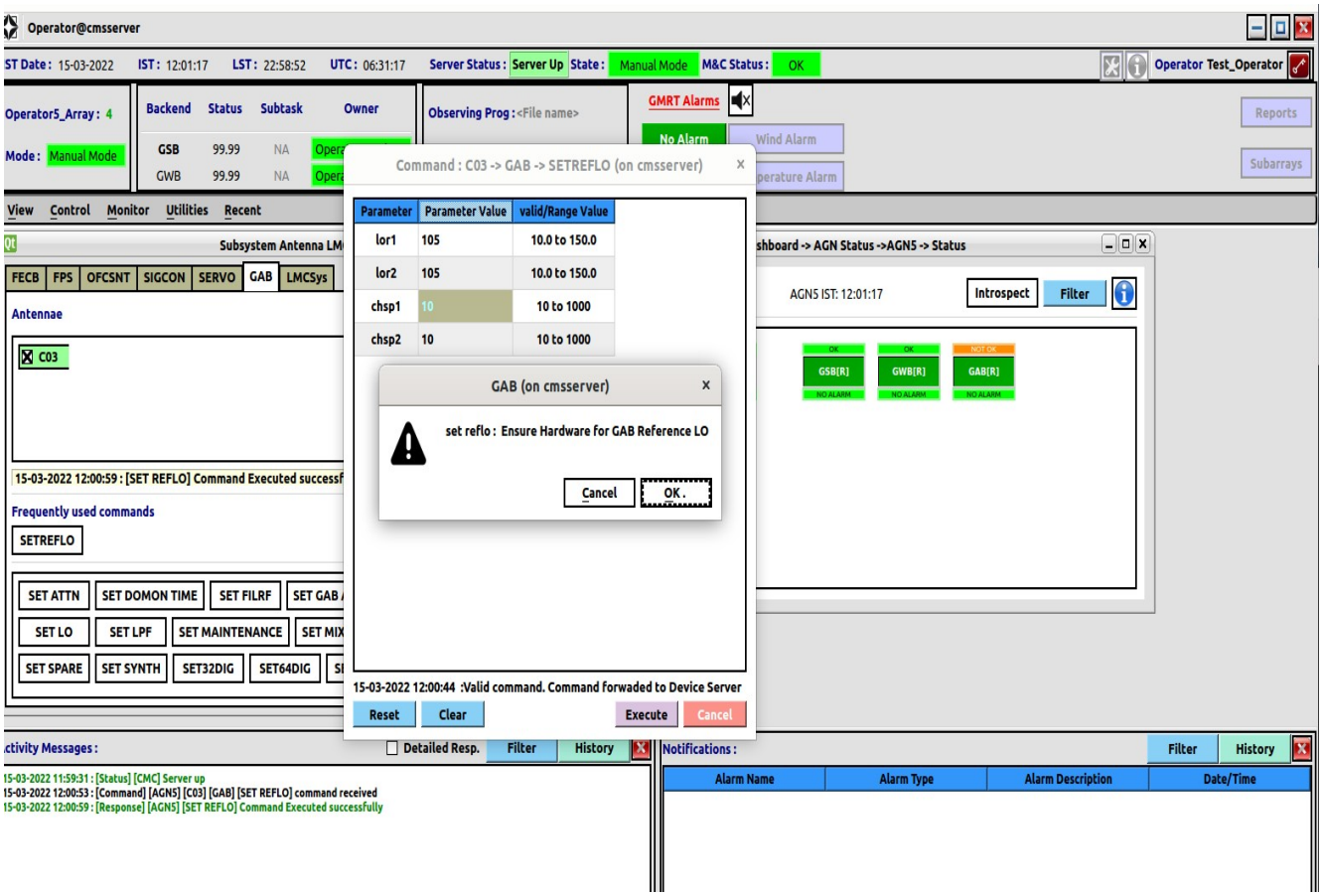


Figure-4 (a) *'set reflo' or SETREFLO command in TGC using the GUI interface*

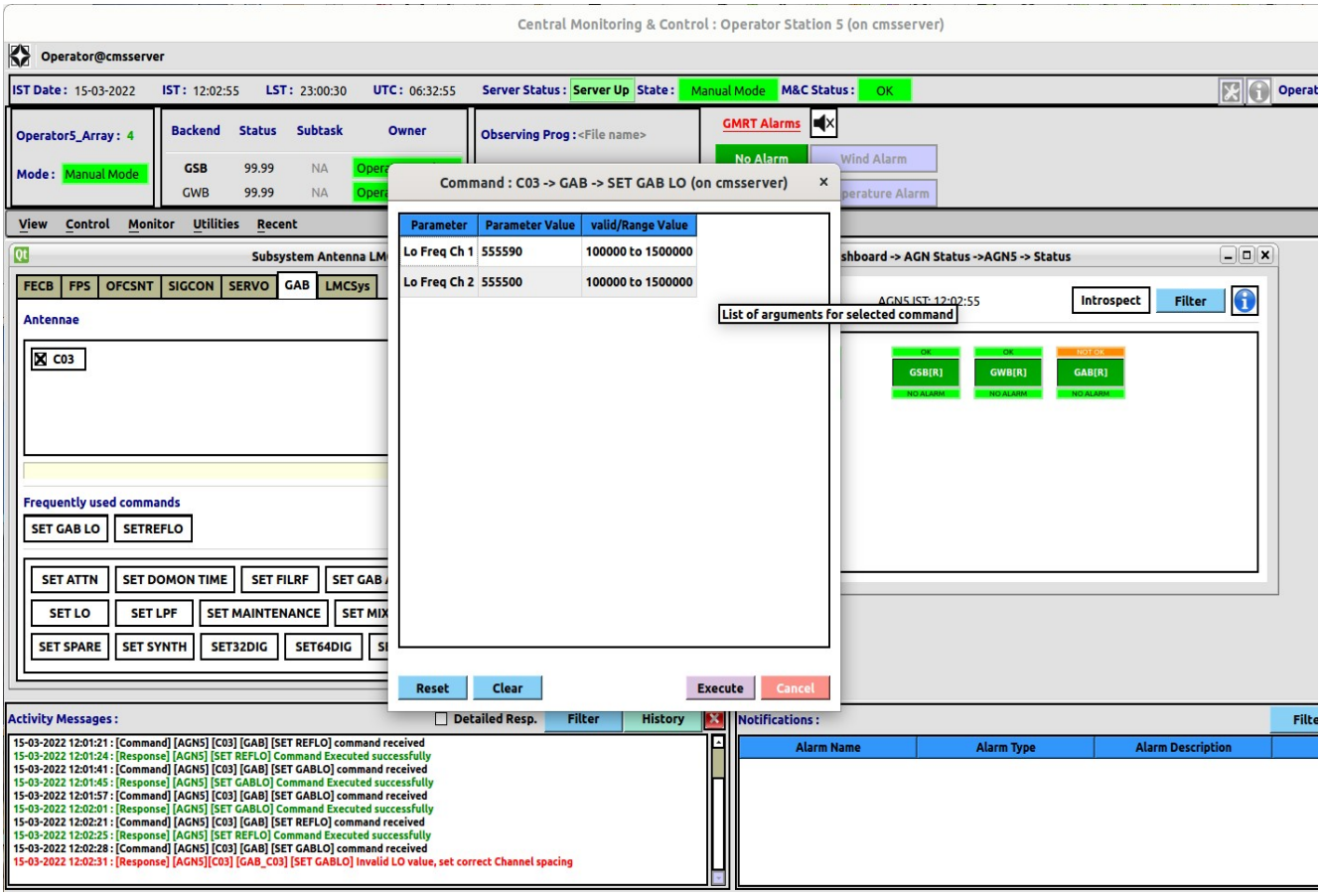


Figure-4 (b) *Invalid LO message when RefLO 105 MHz, and Step-size 1000 KHz*

APPENDIX-I: ADF4351 Functional Block Diagram

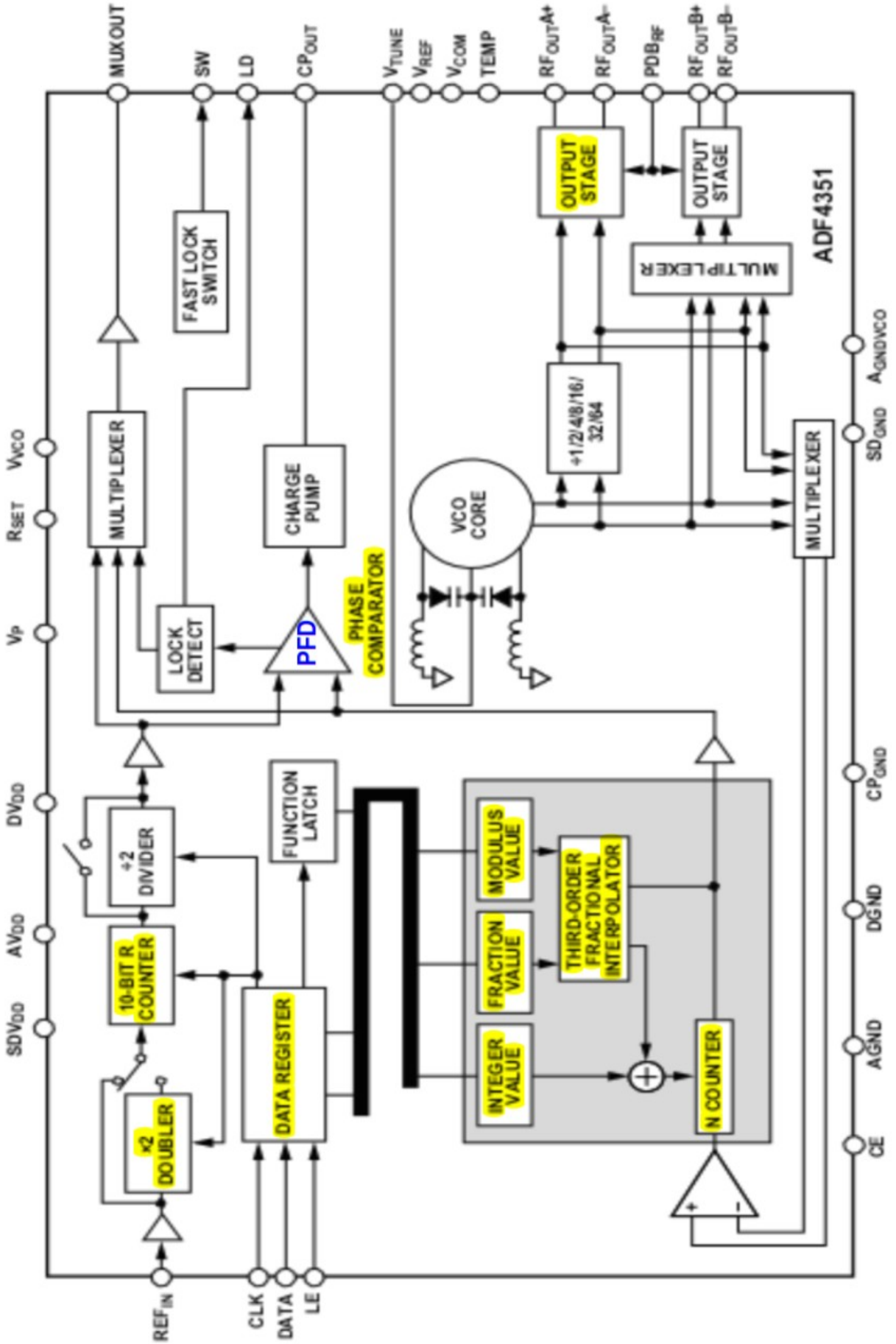


Figure 1.

APPENDIX-II : ADF4351 REGISTER MAPS

REGISTER MAPS

REGISTER 0

RESERVED	INT: 16-BIT INTEGER VALUE (INT)															FRAC: 12-BIT FRACTIONAL VALUE (FRAC)												CONTROL BITS		
DB31	DB30	DB29	DB28	DB27	DB26	DB25	DB24	DB23	DB22	DB21	DB20	DB19	DB18	DB17	DB16	DB15	DB14	DB13	DB12	DB11	DB10	DB9	DB8	DB7	DB6	DB5	DB4	DB3	DB2	DB1	DB0
0	N16	N15	N14	N13	N12	N11	N10	N9	N8	N7	N6	N5	N4	N3	N2	N1	F12	F11	F10	F9	F8	F7	F6	F5	F4	F3	F2	F1	C3(0)	C2(0)	C1(0)

REGISTER 1

RESERVED	PHASE ADJUST	PRESCALER	12-BIT PHASE VALUE (PHASE) DBR[1]	MOD: 12-BIT MODULUS VALUE (MOD) DBR[1]	CONTROL BITS
DB31 DB30 DB29	DB28	DB27	DB26 DB25 DB24 DB23 DB22 DB21 DB20 DB19 DB18 DB17 DB16 DB15	DB14 DB13 DB12 DB11 DB10 DB9 DB8 DB7 DB6 DB5 DB4 DB3	DB2 DB1 DB0
0 0 0	PH1	PR1	P12 P11 P10 P9 P8 P7 P6 P5 P4 P3 P2 P1	M12 M11 M10 M9 M8 M7 M6 M5 M4 M3 M2 M1	C3(0) C2(0) C1(1)

REGISTER 2

RESERVED	LOW NOISE AND LOW SPUR MODES	MUXOUT	REFERENCE DOUBLER DBR[1]	RDIV2 DBR[1]	REF_IN: 10-BIT R COUNTER DBR[1]	DOUBLE BUFFER	CHARGE PUMP CURRENT SETTING DBR[1]	LDF	LDP	PD POLARITY	POWER-DOWN	CP THREE-STATE	COUNTER RESET	CONTROL BITS
DB31 DB30 DB29	DB28 DB27 DB26	DB25	DB24	DB23 DB22 DB21 DB20 DB19 DB18 DB17 DB16 DB15	DB14	DB13	DB12 DB11 DB10 DB9	DB8	DB7	DB6	DB5	DB4	DB3	DB2 DB1 DB0
0 L2 L1	M3 M2 M1	RD2	RD1	R10 R9 R8 R7 R6 R5 R4 R3 R2	R1	D1	CP4 CP3 CP2 CP1	U6	U5	U4	U3	U2	U1	C3(0) C2(1) C1(0)

BSCM

REGISTER 3

RESERVED	BAND SELECT CLOCK MODE	ABP	CHARGE CANCEL	RESERVED	CSR	RESERVED	CLK DIV MODE	12-BIT CLOCK DIVIDER VALUE	CONTROL BITS
DB31 DB30 DB29 DB28 DB27 DB26 DB25 DB24	DB23	DB22	DB21	DB20 DB19	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 D8 D7 D6 D5 D4 D3 D2 D1	C3(0) C2(1) C1(1)

outputdivider_index

REGISTER 4

RESERVED	FEEDBACK SELECT	DBB[2] RF DIVIDER SELECT	8-BIT BAND SELECT CLOCK DIVIDER VALUE	VCO POWER-DOWN	MTLD	AUX OUTPUT SELECT	AUX OUTPUT ENABLE	AUX OUTPUT POWER	RF OUTPUT ENABLE	OUTPUT POWER	CONTROL BITS
DB31 DB30 DB29 DB28 DB27 DB26 DB25 DB24	DB23	DB22 DB21 DB20	DB19 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	D13	D12 D11 D10	BS8 BS7 BS6 BS5 BS4 BS3 BS2 BS1	D9	D8	D7	D6	D5 D4	D3	D2 D1	C3(1) C2(0) C1(0)

REGISTER 5 0X00580005

RESERVED	LD PIN MODE	RESERVED	RESERVED	RESERVED	CONTROL BITS
DB31 DB30 DB29 DB28 DB27 DB26 DB25 DB24	DB23 DB22	DB21	DB20 DB19	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)

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

06666-023

Figure 23. Register Summary

Table – Register-Map values set ***setgabLO*** Simulator or ***Set_LO_Pattern( )*** Rabbit-card Dynamic-C Module

#	ADF4351 Parameter	Register	Data Bit	Range	Remark
1	**INT**	0	30:15	INT Minimum 23 for the 4/5 ***prescalar***, and 75 for 8/9 ***prescalar*** Max – 65,535	The INT value is used in **Equation 1** (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). ***INT = (unsigned int) RF_{OUT}***
2	**FRAC**	0	14:03	0 to MOD - 1	FRAC set the Numerator of fraction that is input to the Σ-Δ 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 **Equation 1**. ***FRAC = (RF_{OUT} – INT) * MOD***
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 **RF_{OUT}**, See **equation (2c)** ***MOD = (unsinged int) ((f_{PFD} / Channel-Spacing) * 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, ***REFin_hex = (unsigned int) REFin*** The 10-bit R-counter allows the input reference frequency (REF IN) to be divided down to produce the reference clock to the PFD. ***R-Counter, R = REF_IN***
6	**Reference Doubler (D)**	2	25	0 or 1	**(i) D= 0: (a)** Disables the doubler, and feeds REFin signal directly into the 10bit R-Counter. **(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. **INT = (unsigned int) Rfout**

					(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. ***INT = (unsigned int) Rfout / 2***
7	**BSCM**	3	23	0 or 1	Band-Select Clock Mode: Default value is 1. Setting the DB23 bit to 1 selects a faster logic 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	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. **(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**
9	**Charge cancel**	3	21	0 or 1	Setting ***charge cancel*** bit to 1 enables charge pump charge cancel action. This has the effect of reducing PFD spurs in integer-N mode. In fractional-N mode, this bit should be set to 0.
10	**RF Divider or outputdivider_index**	4	22-20	0 to 6	**s**elect the value of the RF output divider, based on RFout (or GAB-LO value): ***Rfout < 2200? outputdivider_index = 1; Rfout < 1100? outputdivider_index = 2; Rfout < 550 ? outputdivider_index = 3; Rfout < 275? outputdivider_index = 4; Rfout < 137.5 ? outputdivider_index = 5; Rfout < 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.***

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

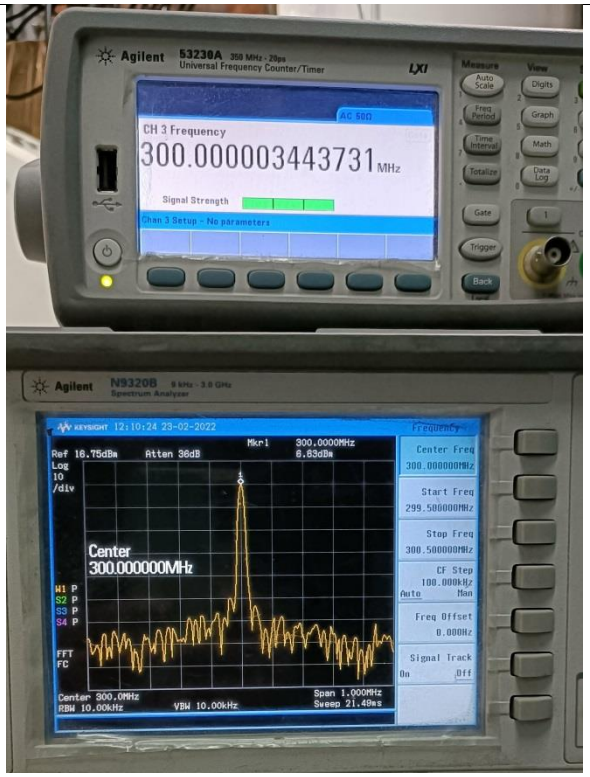
Objective:

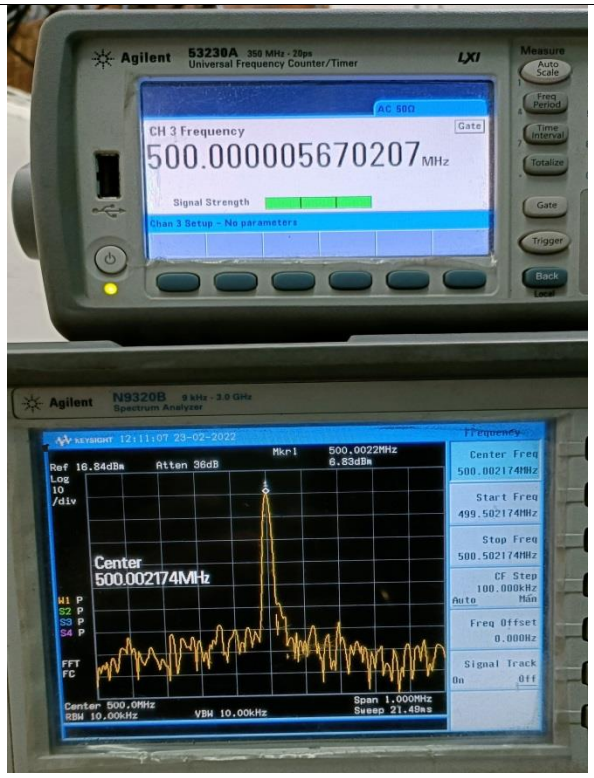
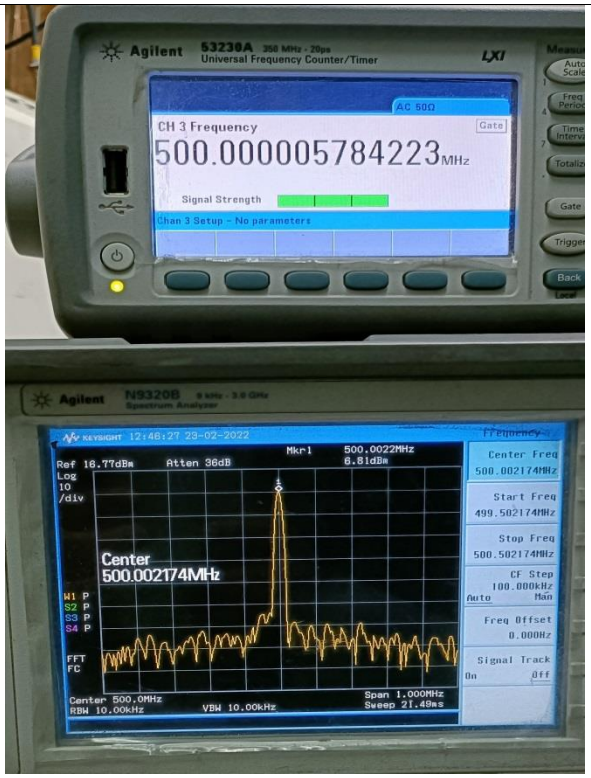
The existing GAB firmware is being revised to provide **default LO reference 105MHz with 1000KHz Step-size**. The revised firmware supports custom LO reference range from **10MHz to 250MHz** with step size ranging **10KHz to 1000KHz.** A separate command is being added in TGC to set any Reference LO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

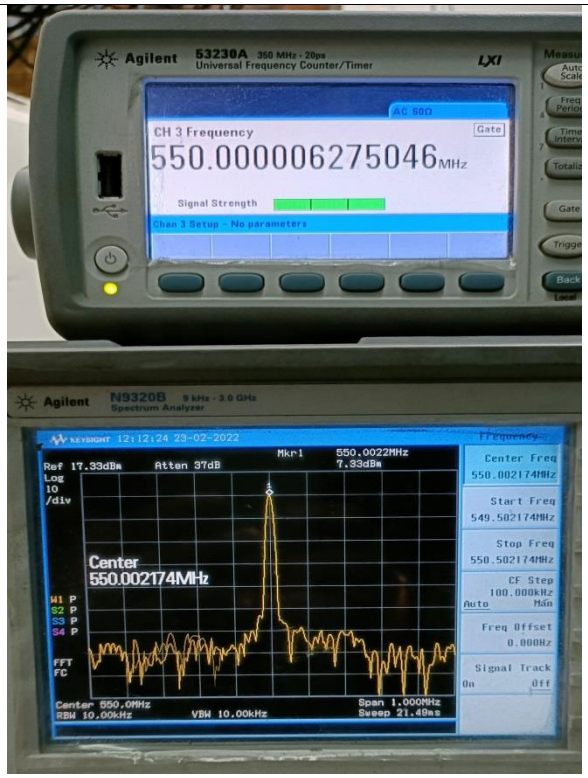
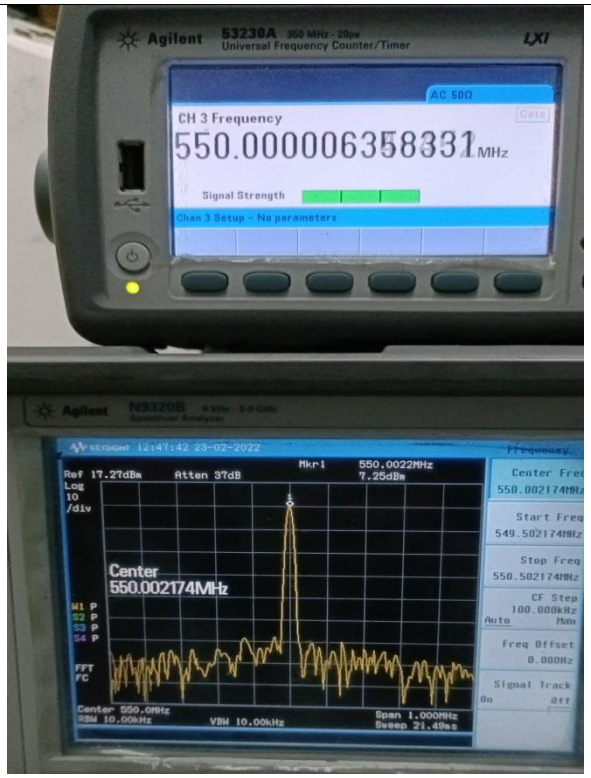
Various combination of GAB-LO using 10MHz and 105MHz reference frequency and varying step-size has been measured using Agilent make Universal Frequency Counter and Spectrum Analyzer.

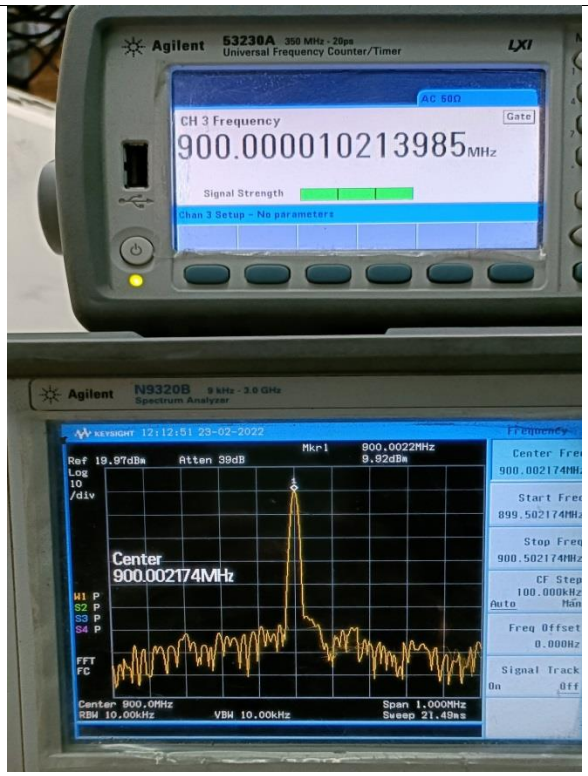
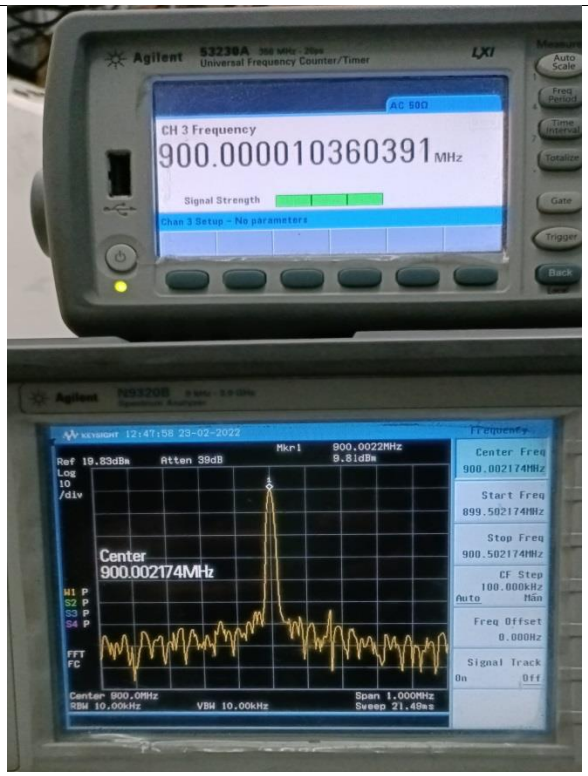
- **Below are the snapshots of the measured GAB-LO using Frequency counter and Spectrum Analyzer.**

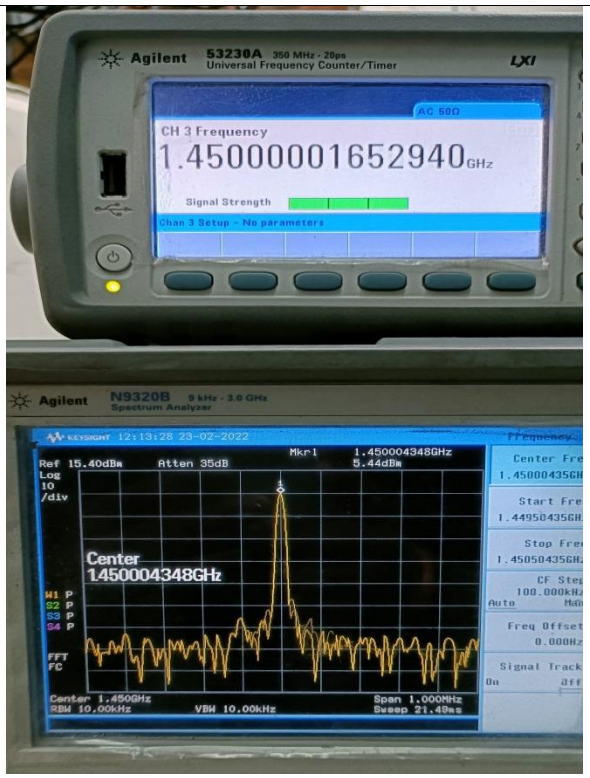
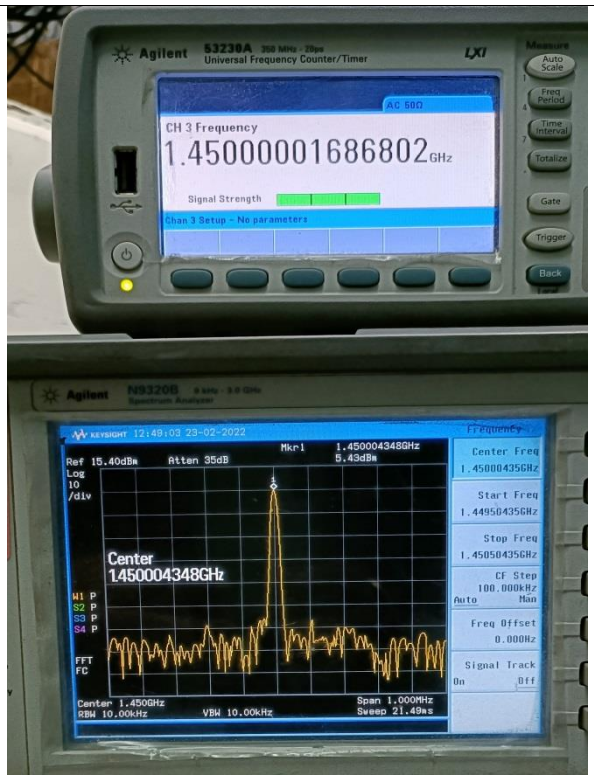
Integer LO Frequencies measurement @ 1000KHz Step-size:

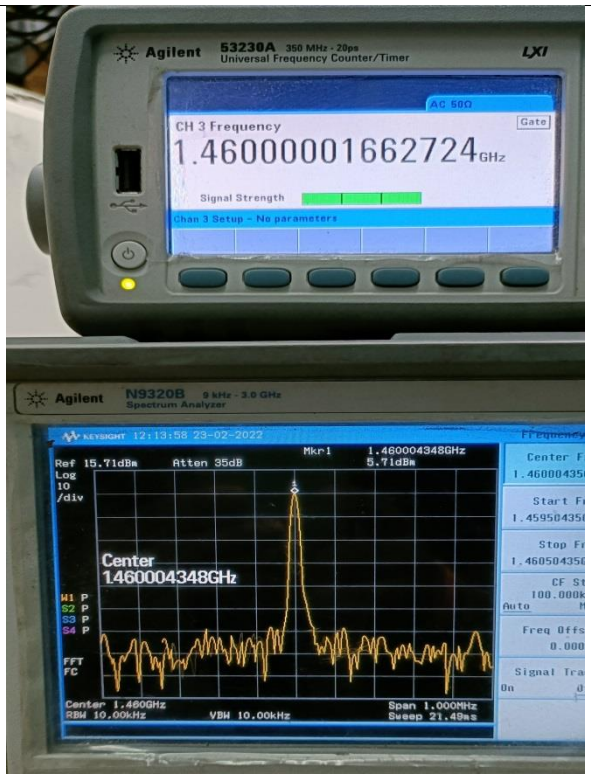
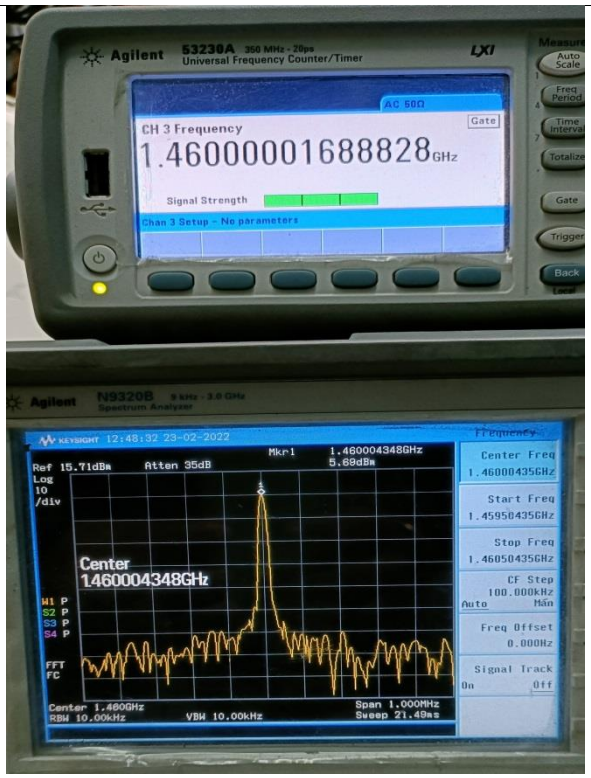
Ref : 10MHz	Ref : 105MHz
	
Freq: 300MHz, Step-size : 1000KHz	**Freq: 300MHz, Step-size : 1000KHz**

Ref : 10MHz	Ref : 105MHz
	
Freq: 500MHz, Step-size : 1000KHz	**Freq: 500MHz, Step-size : 1000KHz**

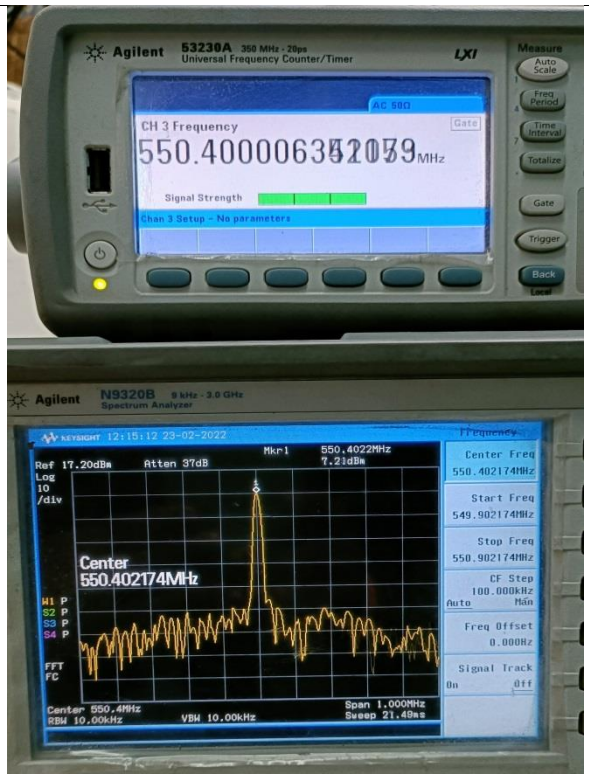
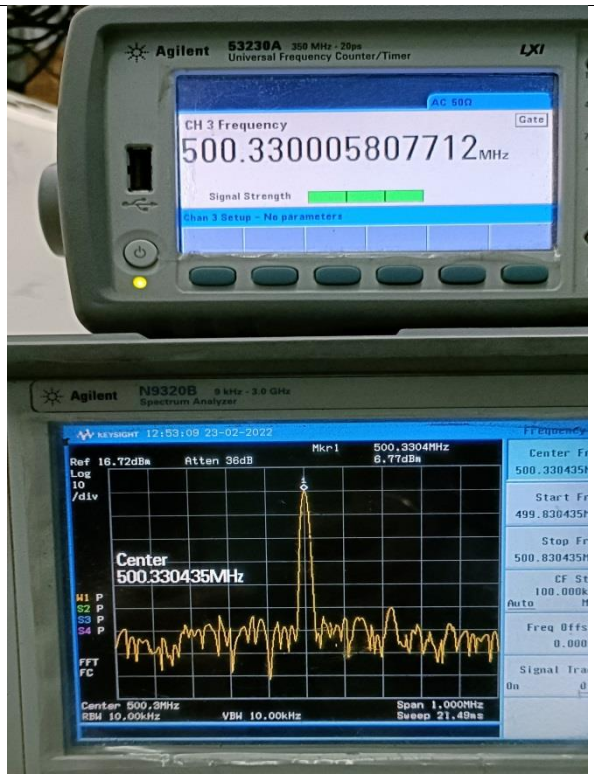
Ref : 10MHz	Ref : 105MHz
	
Freq: 550MHz, Step-size : 1000KHz	**Freq: 550MHz, Step-size : 1000KHz**

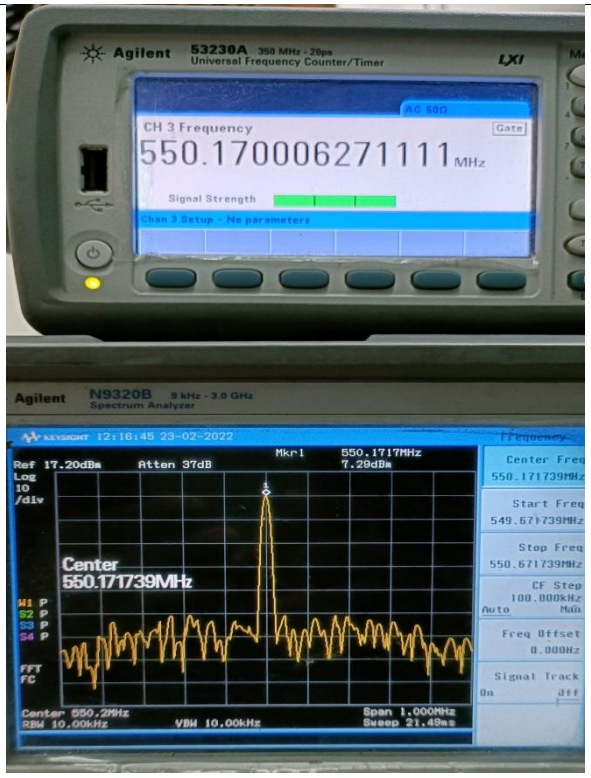
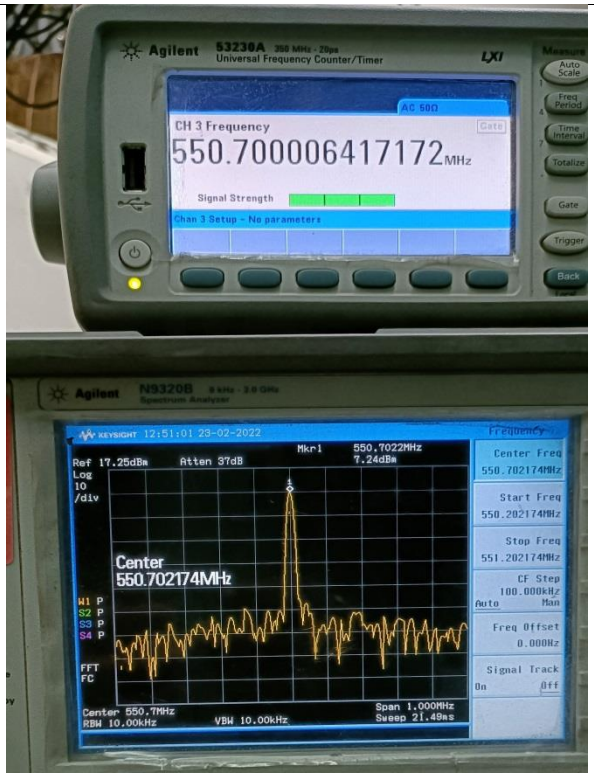
Ref : 10MHz	Ref : 105MHz
	
Freq: 900MHz, Step-size : 1000KHz	**Freq: 900MHz, Step-size : 1000KHz**

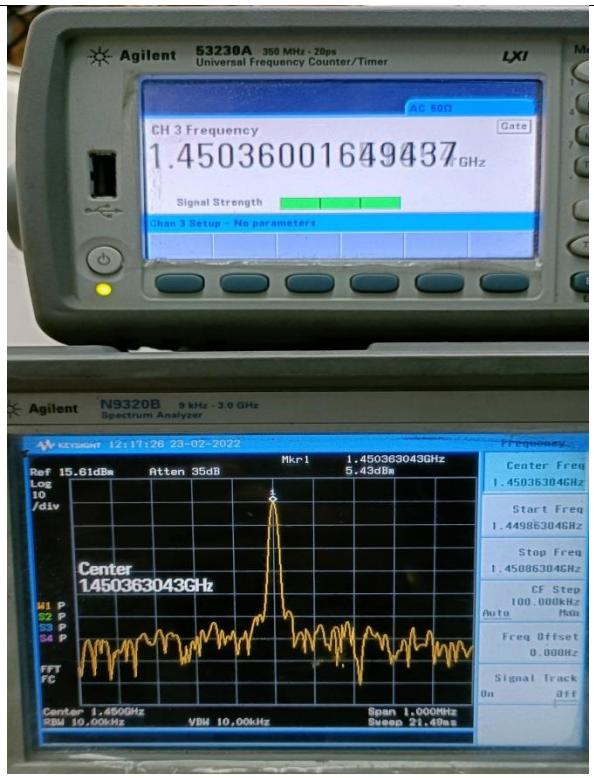
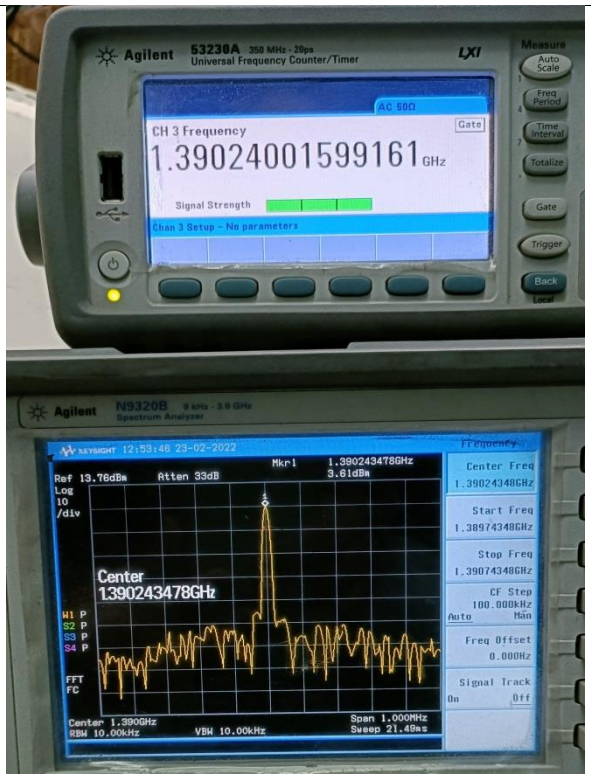
Ref : 10MHz	Ref : 105MHz
	
Freq: 1450MHz, Step-size : 1000KHz	**Freq: 1450MHz, Step-size : 1000KHz**

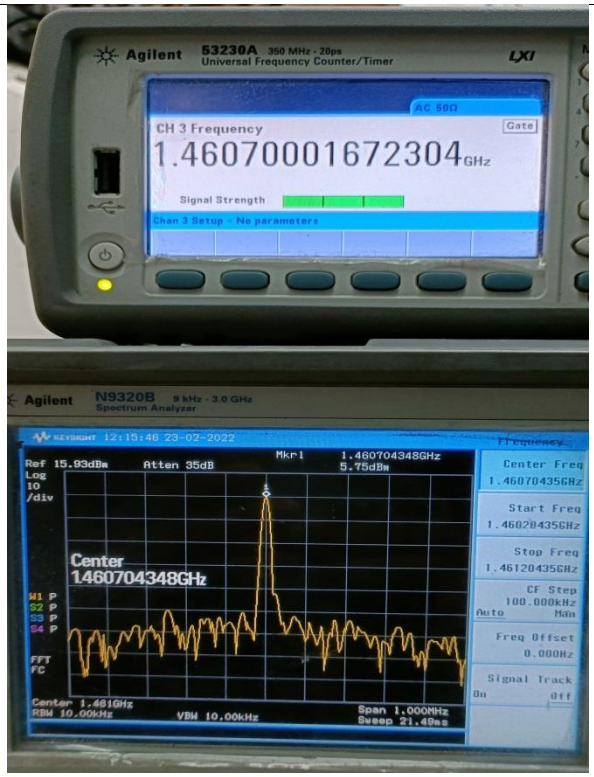
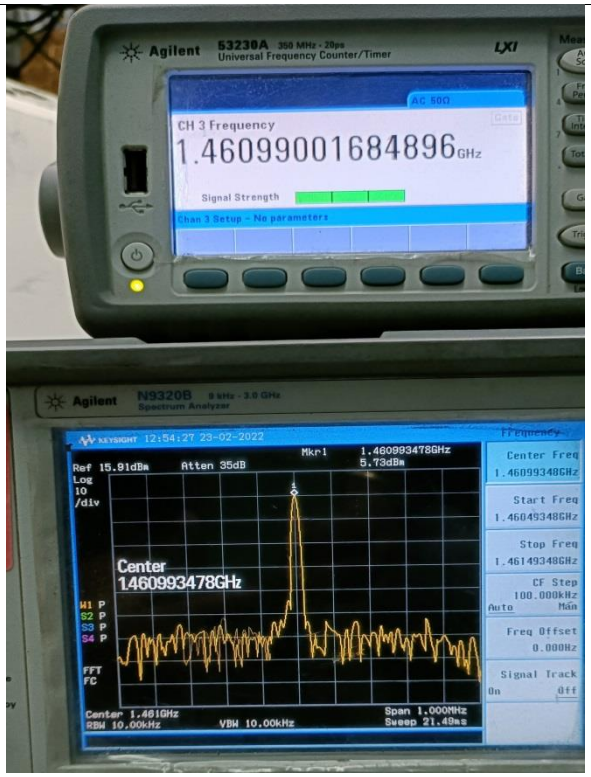
Ref : 10MHz	Ref : 105MHz
	
Freq: 1460MHz, Step-size : 1000KHz	Freq: 1460MHz, Step-size : 1000KHz

- **Fractional LO Frequencies measurement @ 10KHz Step-size :**

Ref : 10MHz	Ref : 105MHz
	
Freq: 550.40MHz, Step-size : 10KHz	**Freq: 500.33MHz, Step-size : 10KHz**

Ref : 10MHz	Ref : 105MHz
	
Freq: 550.17MHz, Step-size : 10KHz	**Freq: 550.70MHz, Step-size : 10KHz**

Ref : 10MHz	Ref : 105MHz
	
Freq: 1450.36MHz, Step-size : 10KHz	**Freq: 1390.24MHz, Step-size : 10KHz**

Ref : 10MHz	Ref : 105MHz
	
Freq: 1460.70MHz, Step-size : 10KHz	**Freq: 1460.99MHz, Step-size : 10KHz**

- **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.