Introduction to Synchronization

Frequency, Time, and Phase

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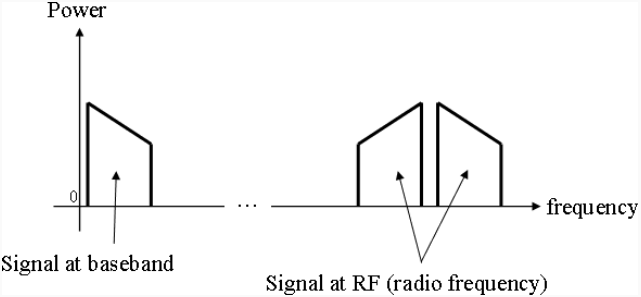
Introduction

- GNU Radio has many DSP synchronization blocks, not talking about them
- Synchronization of the physical radio(s)
- Frequency, Time, Phase
- Overview of the problem

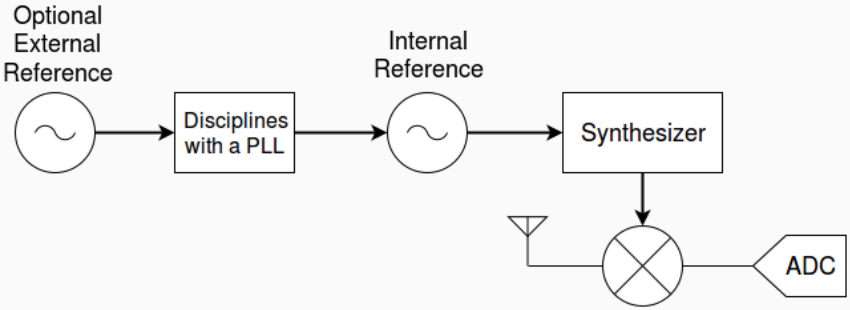
Frequency

CARRIER FREQUENCY

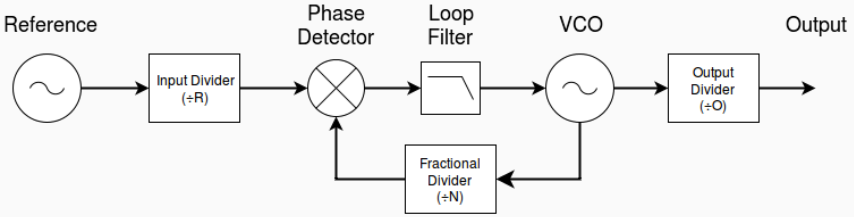
- Baseband signals are mixed with a carrier for transmission
- Carrier has frequency and phase information
- Received signals are mixed with a carrier generated locally



- Frequency accuracy and stability depends on the reference oscillator
- Usually a fractional-N based synthesizer

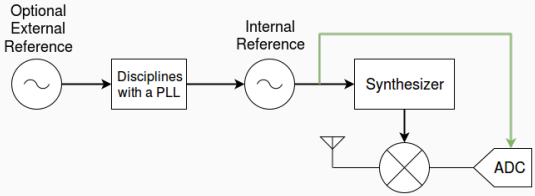


- Generate output frequencies from a reference using a control loop comparing phases



SAMPLE CLOCKS

- ADCs and DACs often accept external clock signals
- Sampling clock offsets present as time shifts
- Sampling clock jitter presents as phase noise



GRADES OF REFERENCES

$$\text{Fractional Frequency Error} = \frac{Frequency_{measured} - Frequency_{nominal}}{Frequency_{nominal}}$$

Source	Accuracy	Error[1]
Crystal	10^{-5}	1 Hz at 100 kHz
TCXO	10^{-6}	1 Hz at 1 MHz
OCXO	10^{-8}	1 Hz at 100 MHz
Rubidium	10^{-11}	1 Hz at 100 GHz
Cesium	10^{-14}	1 Hz at 100 THz

[1] https://www.febo.com/pages/stability/

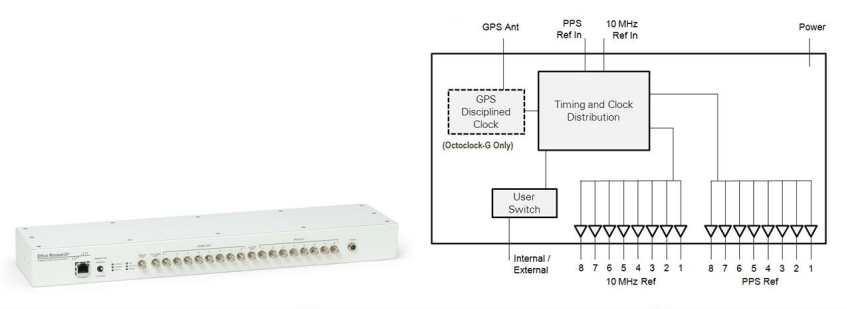
Time

TIME SENSITIVE OPERATIONS

- Many applications require high precision timestamps
- Timestamping on the host is degraded by processing and transport latency
- Useful, or essential, to have time available on the device
- Tuning, Antenna switching, start/stop of sampling

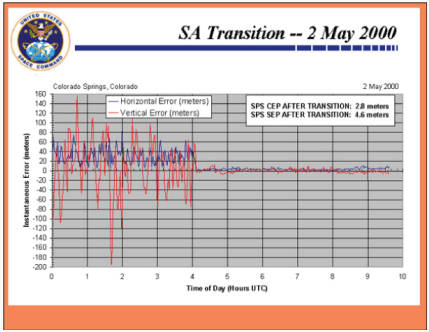
1 PULSE PER SECOND

- Precision timing source
- Commonly output by GPSDOs



GPS TIME REFERENCES

- Globally available time reference
- 10-50 nS accuracy
- Good enough for frequency and (usually) time synchronization
- At 200 MSPS equates to a 2-10 sample error
- Can be onboard or external



Phase

- Remember, we're talking about physical phase synchronization
- Beamforming, Direction Finding, self cancellation have strict phase synchronization requirements

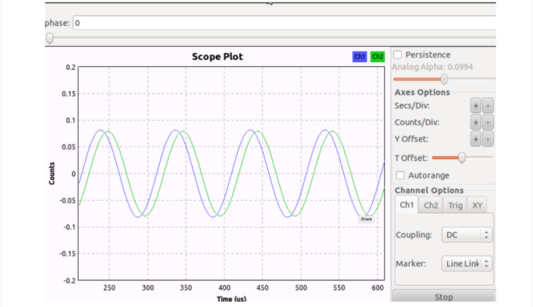


Figure 7– Time Domain Display Showing Received Signal before Phase Compensation

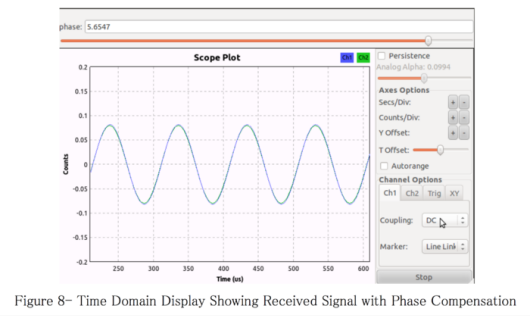
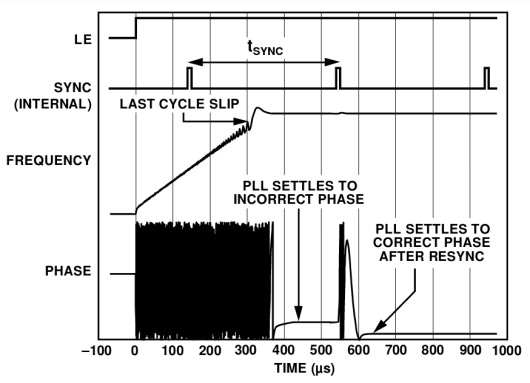


Figure 8– Time Domain Display Showing Received Signal with Phase Compensation

SYNTHESIZERS REVISITED

- Phase ambiguities introduced because of dividers and architecture
- Many synthesizers can synchronize their output signal's phase with respect to the input reference
- Sometimes automatic, sometimes requires external signals



TIMED COMMANDS

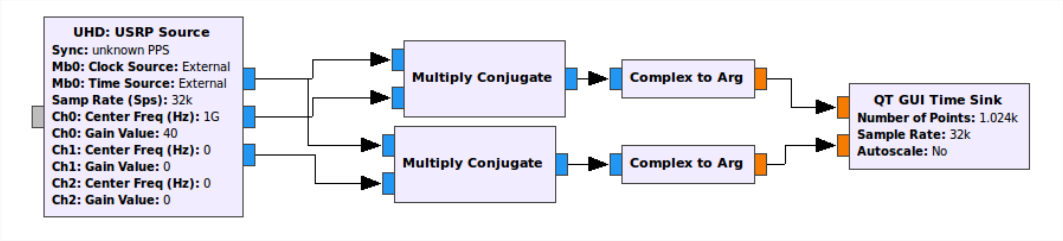
- Phase synchronization is always between two or more signals
- Requires frequency synchronization first
- Requires time synchronization (or shared signals) for commands to the synths

PHASE OFFSETS

- Even with frequency and time alignment and phase resync offsets may still exist
- Differences in layout between channels on multichannel receivers, cable lengths, thermal...
- Easy to calibrate as long as offsets are constant across tunes and power cycles

PHASE OFFSET MEASUREMENT

- Multiplying one signal by the complex conjugate of another gives the offset
- A correction can be applied to each signal using a multiplication



Conclusion

SUMMARY

- Different applications require different levels of synchronization
- Shared physical references are convenient but still require attention to detail
- GNU Radio has a variety of DSP based synchronization utilities

QUESTIONS

Questions?

The latest version of these slides can always be found at
`http://www.derekkozel.com/talks`

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COLOPHON

The presentation was created using XeTeX and Beamer using the Metropolis theme.

`github.com/matze/mtheme`