THE *ANTELOPE* MICROWAVE TRANSCEIVER

10 GHz and Down

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Introduction

- A 10 GHz-and-down MW Transceiver
- Motivation
- Design Goals
- LO Tricks

Introduction

- The Transceiver
  - Covers 10 GHz-and-down MW
  - Modular design for release as a kit
  - 3-IF radio with digital back-end
  - Multi-purpose broadband 44 MHz IF
  - An inverted LO structure
- Modular frontends
  - 5.7 & 10.4 GHz module
  - 902 through 3.45 GHz module
  - UHF & VHF module

Introduction

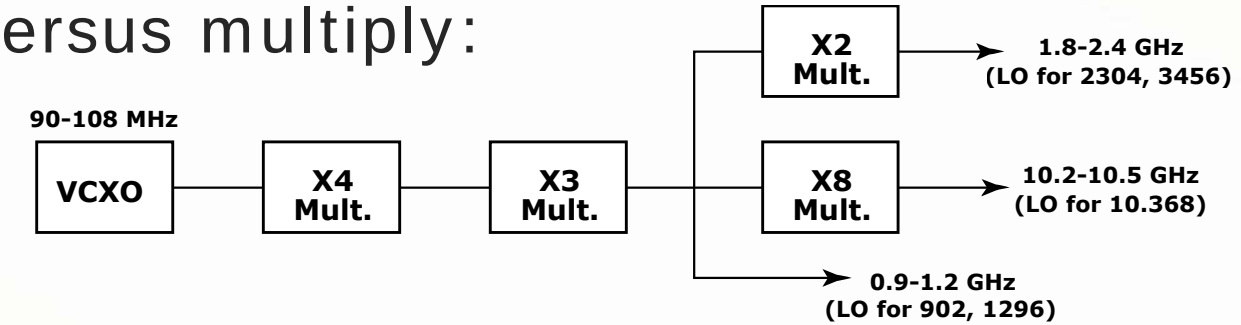
- Motivations
  - Personal challenge to push myself
  - RF: Hobby versus professional life
  - Club project opportunity
  - Possible business opportunity

Introduction

- Design Goals
  - Support 10.368 thru 1296, minimum
  - Support as many bands as possible
  - Use no LO multipliers
  - Share same LO source on all bands
  - LO noise on worst band should be < -110 dBc/root Hz.
  - Waste (cheap) active devices
  - No relays
  - Use QSD/QSE modulation and/or digital base-band processing.

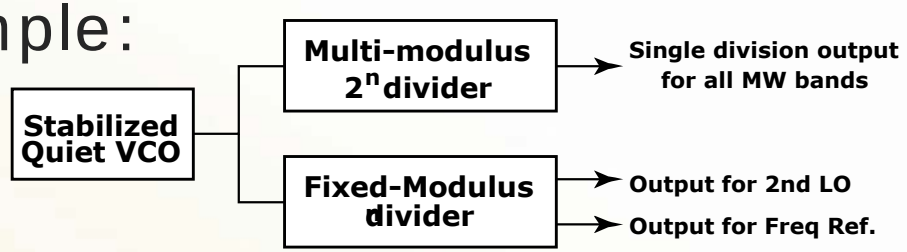
Introduction

- LO Tricks
  - Divide versus multiply:



Typical MW Local Osc. Multiplier Chain

  - Clean, simple:



Antelope Local Oscillator Dividers

IF Frequency Planning

- Initial Challenges:
  - Devise a system where the LO signals are confined to a single device until their point of need. (Minimize stray radiation.)
  - Find a magic frequency.
  - Hit all bands with as little “IF hop” as possible.
  - Find a common 3rd (SDR) IF near 40 MHz.
  - Preserve band space for 4 MHz wide upper IFs.

IF Frequency Planning

- After much spreadsheet work, 9.1000 GHz was chosen as reasonably optimum.
- Hittite fixed- and variable-modulo dividers are available to support final choices.
- 1st IF falls in range of 1.168 and 1.268 GHz for 2304 and up.
- 1st IF falls in range of 65 and 235 MHz for 220 through 1296 MHz.
- 2nd IF (where used) ranges from 29 through 159 MHz, for 1296 through 10.384.

IF Frequency Planning

- LOs for 1st and 2nd IFs derive from dividers.
- LO for 3rd IF is from an agile VHF source.
- LO for 3rd IF is the (cheap version of the) Si-570.
- The Si-570 – or equivalent - loafs along across the range of 71 through 279 MHz.

IF Frequency Planning

- The frequency planning spreadsheet:

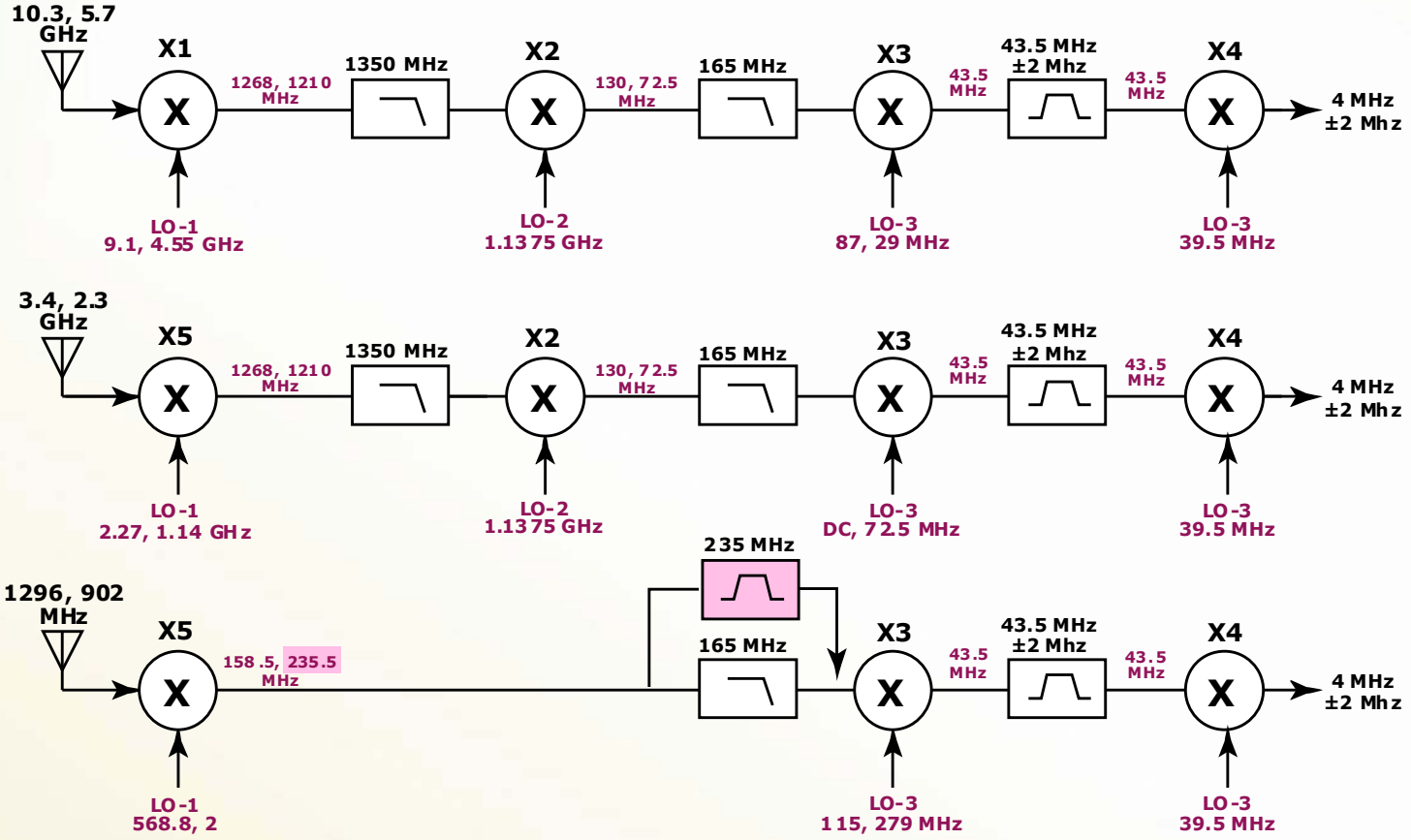
				Microwave 11-Band Frequency Planner					
	B	C	D	E	F	G	H	I	J
	RF (GHz)	LO1 (GHz)	IF1 (MHz)	IF1 Remarks	IF2 (MHz)	IF2 Remarks	LO2 (570)	SDR-IF	IF3 Remarks
4	10.368	9.1000	1268.0	IF1 = RF - LO1	130.50	IF2 = IF1 - C7a	87.00	43.50	IF3 = IF2 - LO2
5	5.760	4.5500	1210.0	IF1 = RF - LO	72.50	IF2 = IF1 - C7a	29.00	43.50	IF3 = IF2 - LO2
6	3.456	2.2750	1181.0	IF1 = RF - LO	43.50	IF2 = IF1 - C7a	(DC)	43.50	IF3 = IF2
7	2.304	1.1375	1166.5	IF1 = RF - LO	29.00	IF2 = IF1 - C7a	-72.50	43.50	IF3 = IF2 - LO2
8	1.296	1.1375	158.50	IF1 = RF - LO	158.50	IF2 = RF - C7a	115.00	43.50	IF3 = IF2 - LO2
9	0.902	1.1375	-235.50	IF1 = RF - LO			-279.00	43.50	IF3 = IF1 - LO2
10	0.432	0.5688	-136.750	IF1 = RF - LO			-180.25	43.50	IF3 = IF1 - LO2
11	0.220	0.2844	-64.375	IF1 = RF - LO			-107.88	43.50	IF3 = IF1 - LO2
12	0.144						100.50	43.50	IF3 = RF - LO2
13	0.050		Non-used frequency space				-93.50	43.50	IF3 = RF - LO2
14	0.028						-71.50	43.50	IF3 = RF - LO2

The RF Structure

- The structure initially looks pretty excessive with brute force implementation.
- Design initially compacted to reuse blocks, with (6) RF switches.
- The compacted structure was then again simplified using diplexers, eliminating some switches.
- The following drawings ignore gain blocks, for simplicity.

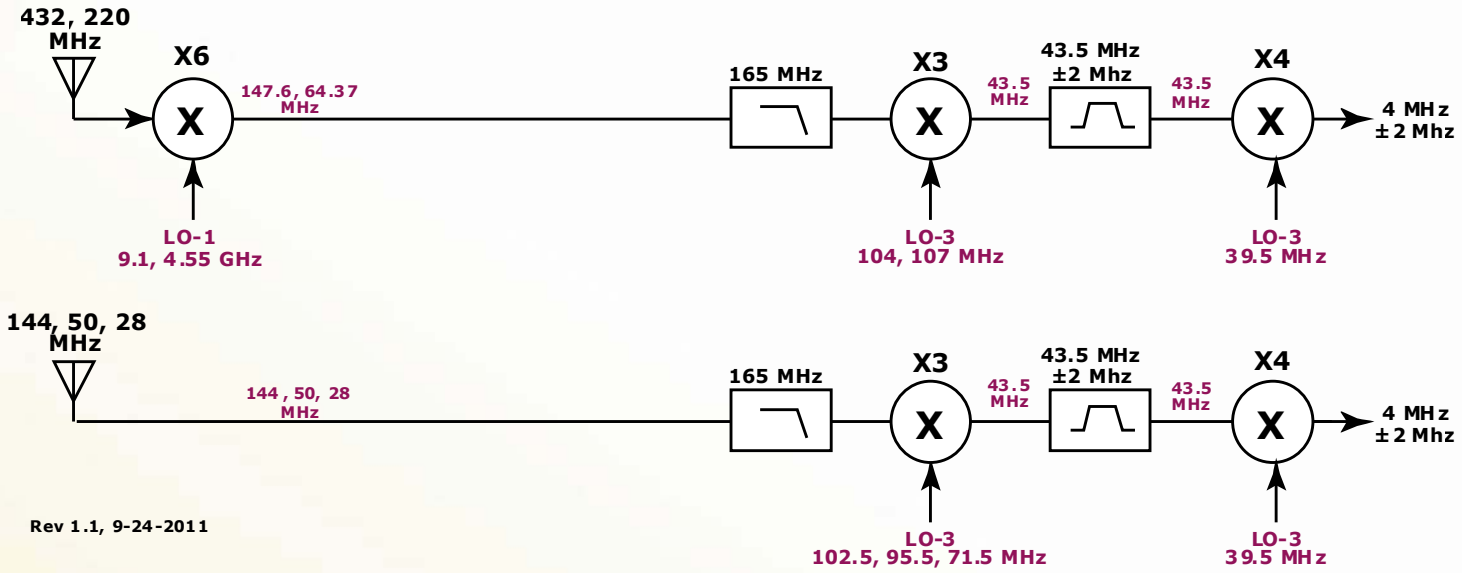
The RF Structure

- The upper bands (unrolled):

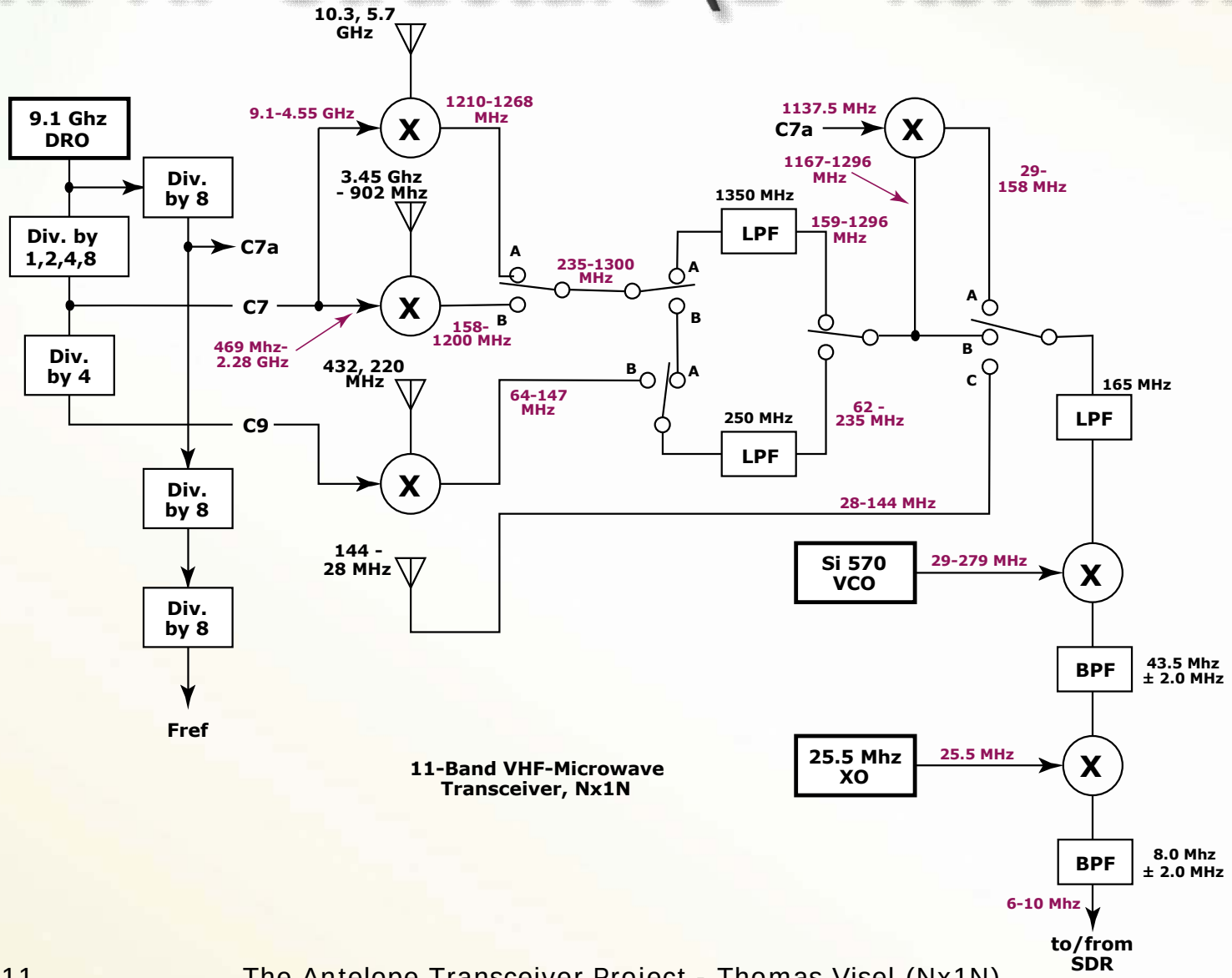


The RF Structure

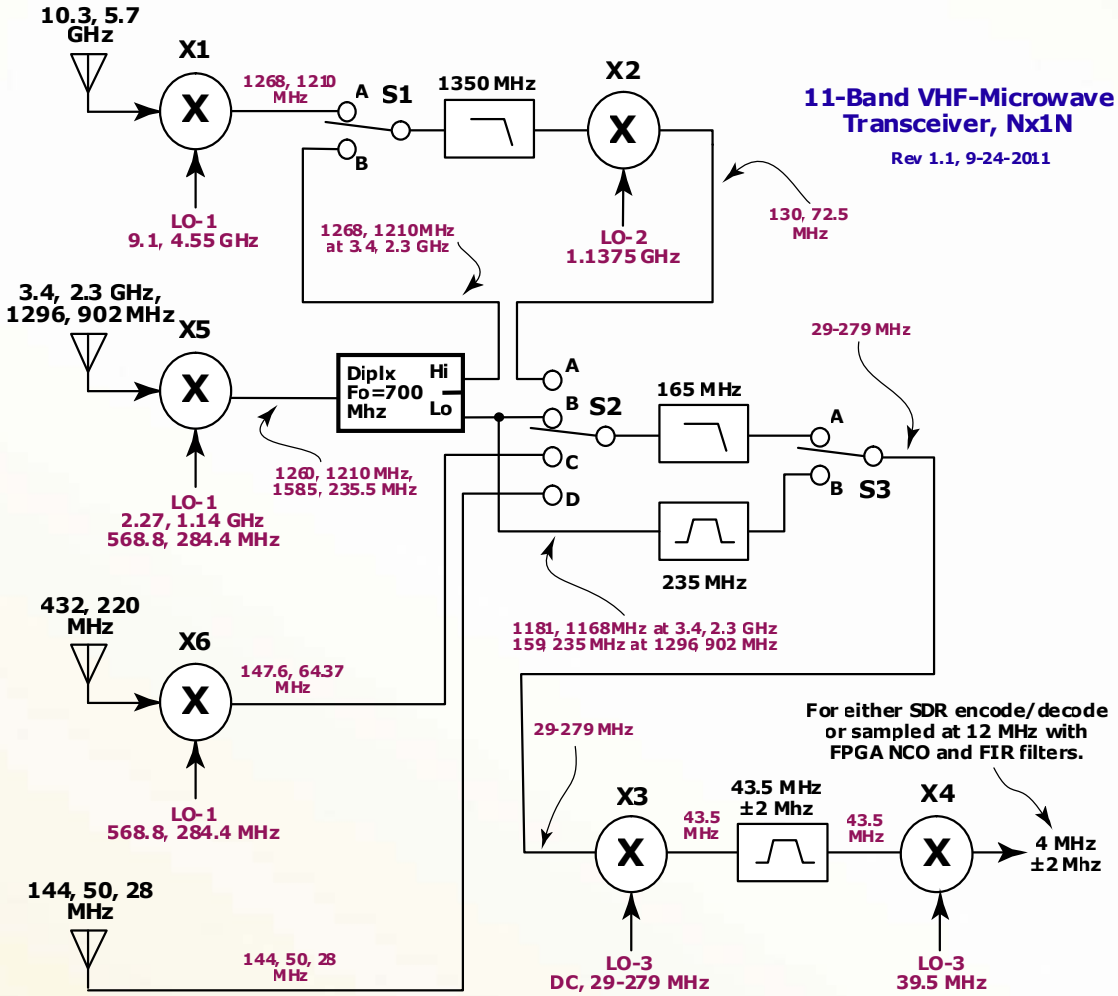
- The UHF/VHF bands (unrolled):



The RF Structure (2nd Iteration)



RF Structure (3rd Iteration)



Mixers

- Mixer availability determined upper-band module partitioning.
- Transformers in the Mini-Circuits SIM-153MH+ mixer limit it to 3.2 – 15 GHz.
- Both MW modules use +13 dBm mixers.
  - High intermod tolerance
  - Suitable for bi-directional use

Filters

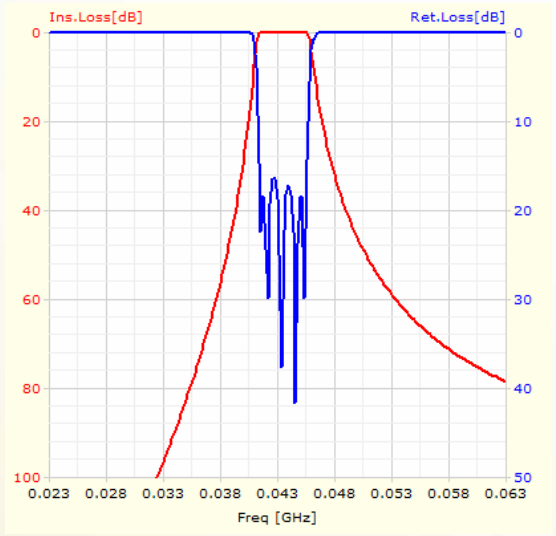
- Band-specific filters are external to the modules.
- All mixers terminate in a low-pass filter (for receive).
- A ±90º splitter used at 700 MHz as a diplexer, eliminating 3 RF switches.
- The 1350 MHz signal is present as 2nd LO for all bands 2304 and up.
- Another 1350 MHz signal is selectively created to handle 902 thru 2304 1st LO.

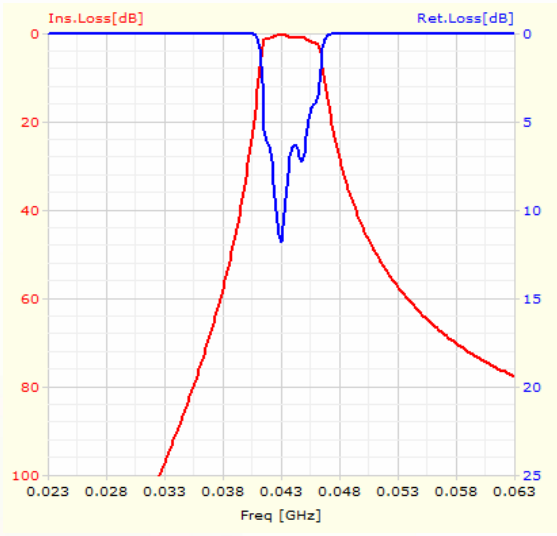
Design Tools

- Design and simulation is done using *Ansoft Designer (SV)*, ACS *Linc2* and a bit of Agilent *AppCad* here and there.
- *Designer* has better variety of filter design tools, but is a restricted version for large-system designs.
- *Linc2* is handles full-system simulations and seems easier to tweak matching with.

Implementation Challenges

- 4 MHz BW filter at 43 MHz is tough.
- 1-2% parts are needed. Below bandpass curves with 1 part varied from 116 pF to 110 pF:



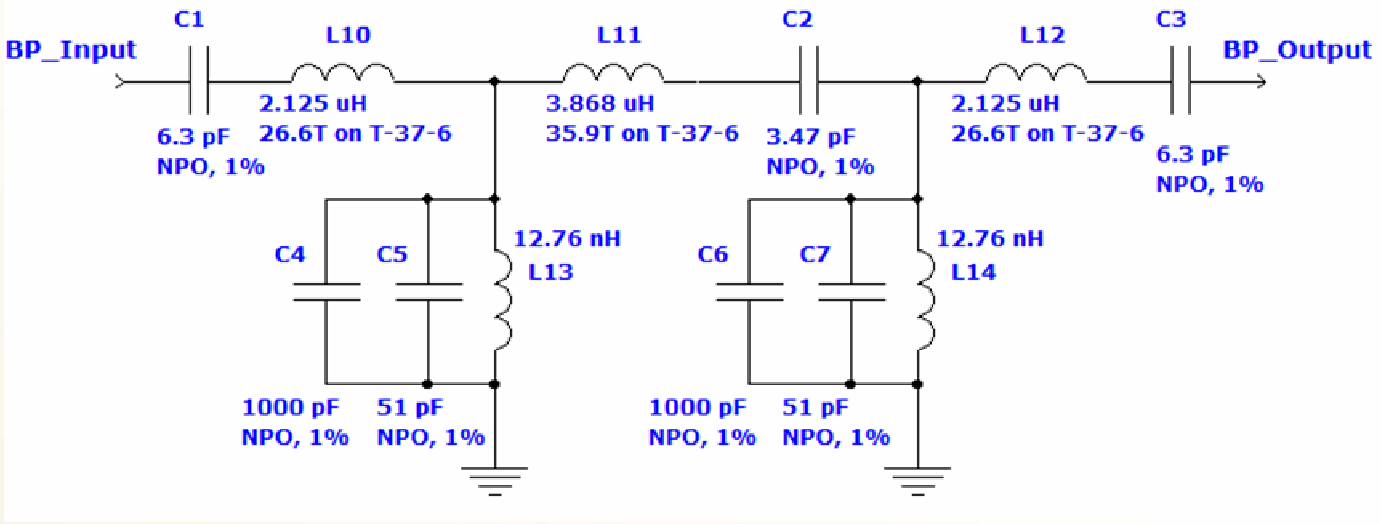


Design Sequence Choice

- Detailed design of the 43.5±2 MHz IF module was undertaken first.
  - It was always the portion that scared or challenged me.
  - That IF module has multiple applications:
    - The *Antelope* transceiver
    - A wideband panadapter
    - A low-cost FM comm link
  - It gives a foundation for checkout/debug
  - It can drive existing SDR gear.

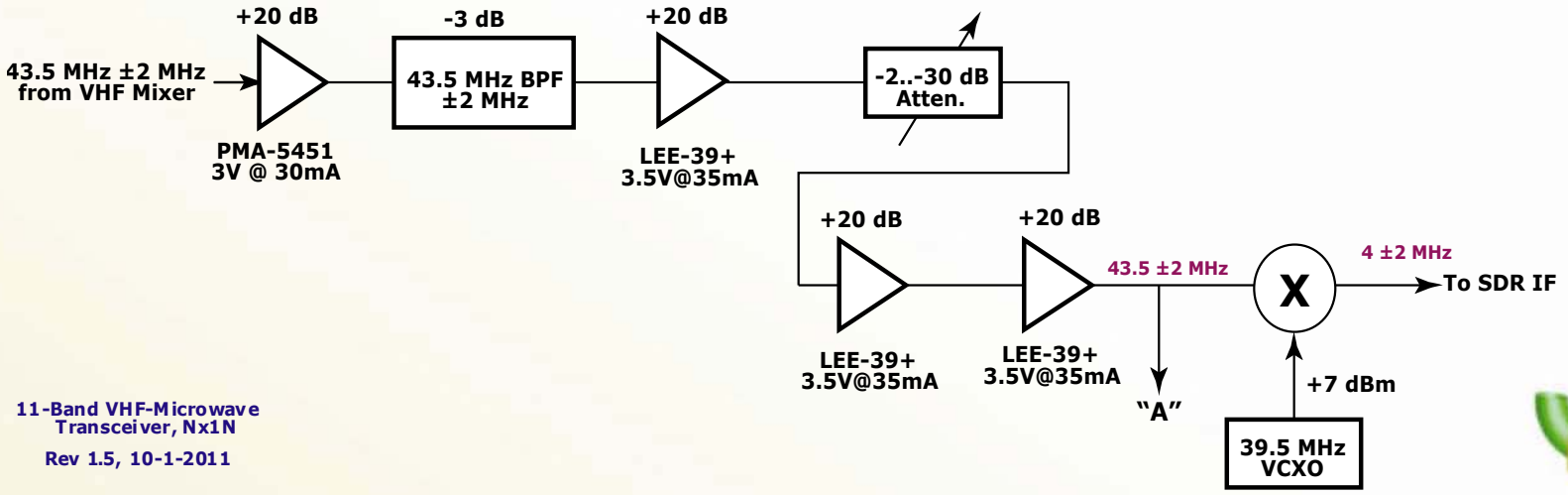
Wideband IF Filter

- Designed with *Ansoft Designer* as a "constricted passband" filter.
- Tweaked using *Linc2* to estimate component tolerances.

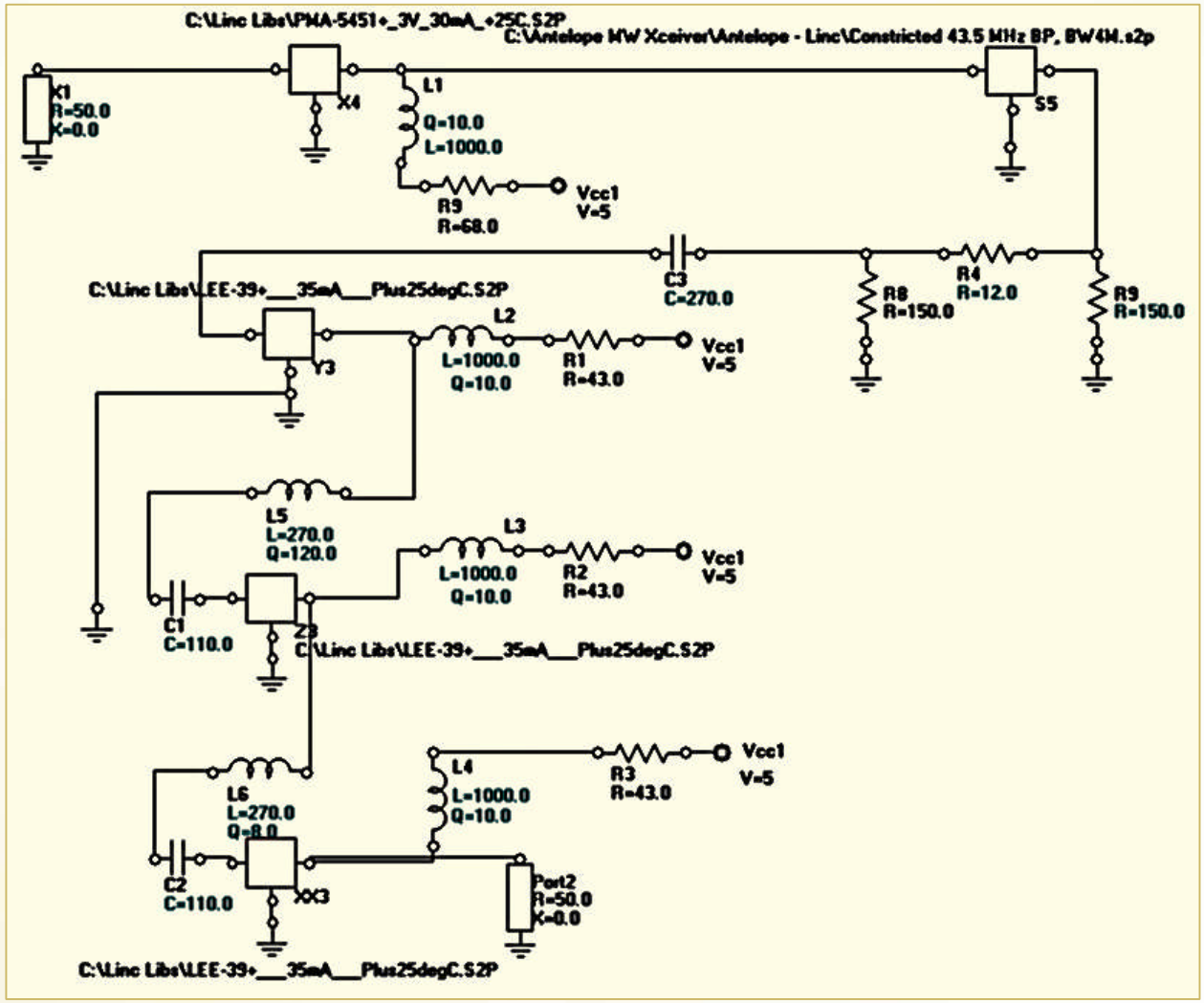


The 43.5 MHz IF Module

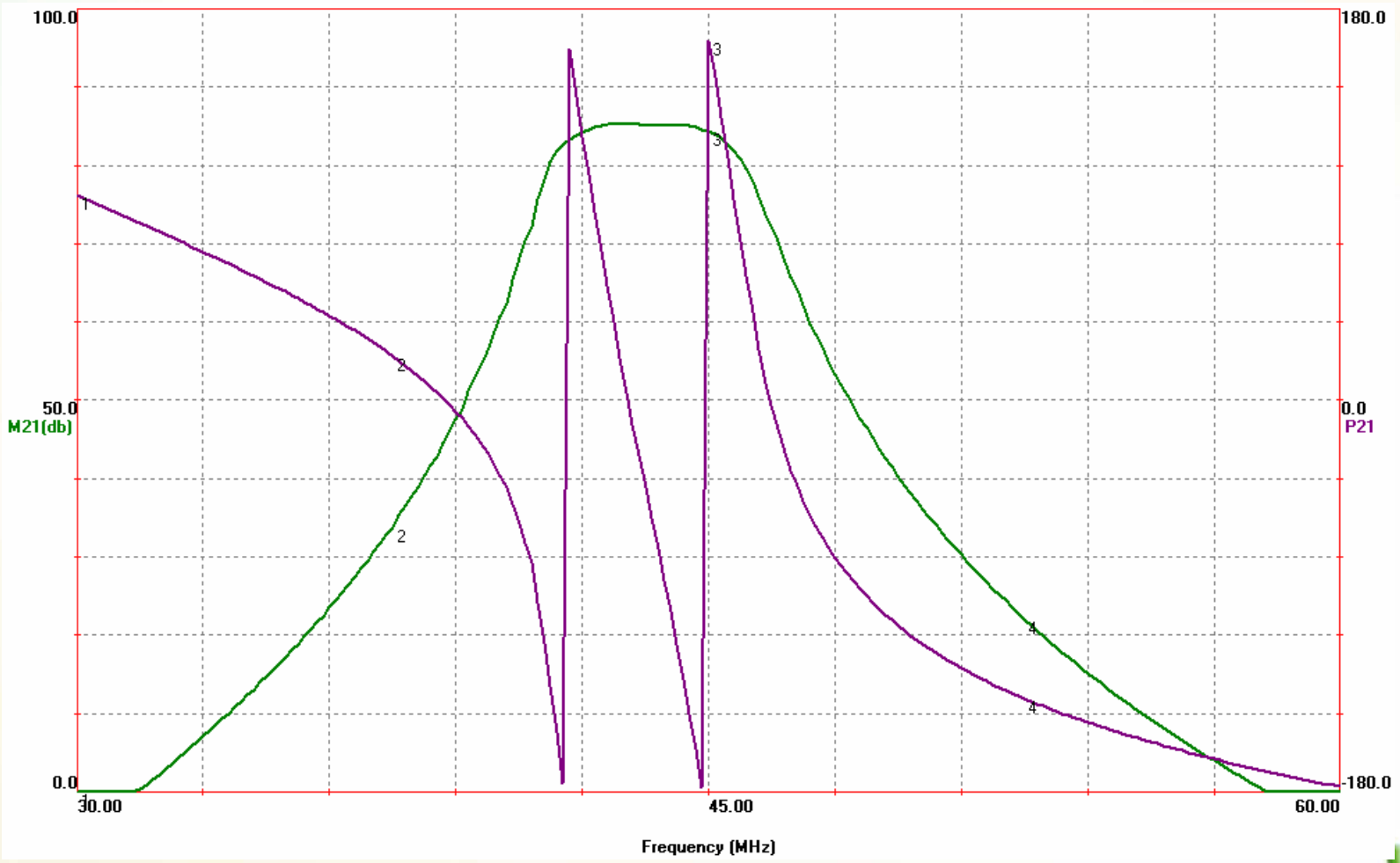
- Goals:
  - 80 dB gain, flat over 4 MHz
  - 1.5 dB noise figure
  - Deliver max of +1 dBm at output
- Simulation shows 85 dB gain, w/filters.



The *Linc*2 Simulation



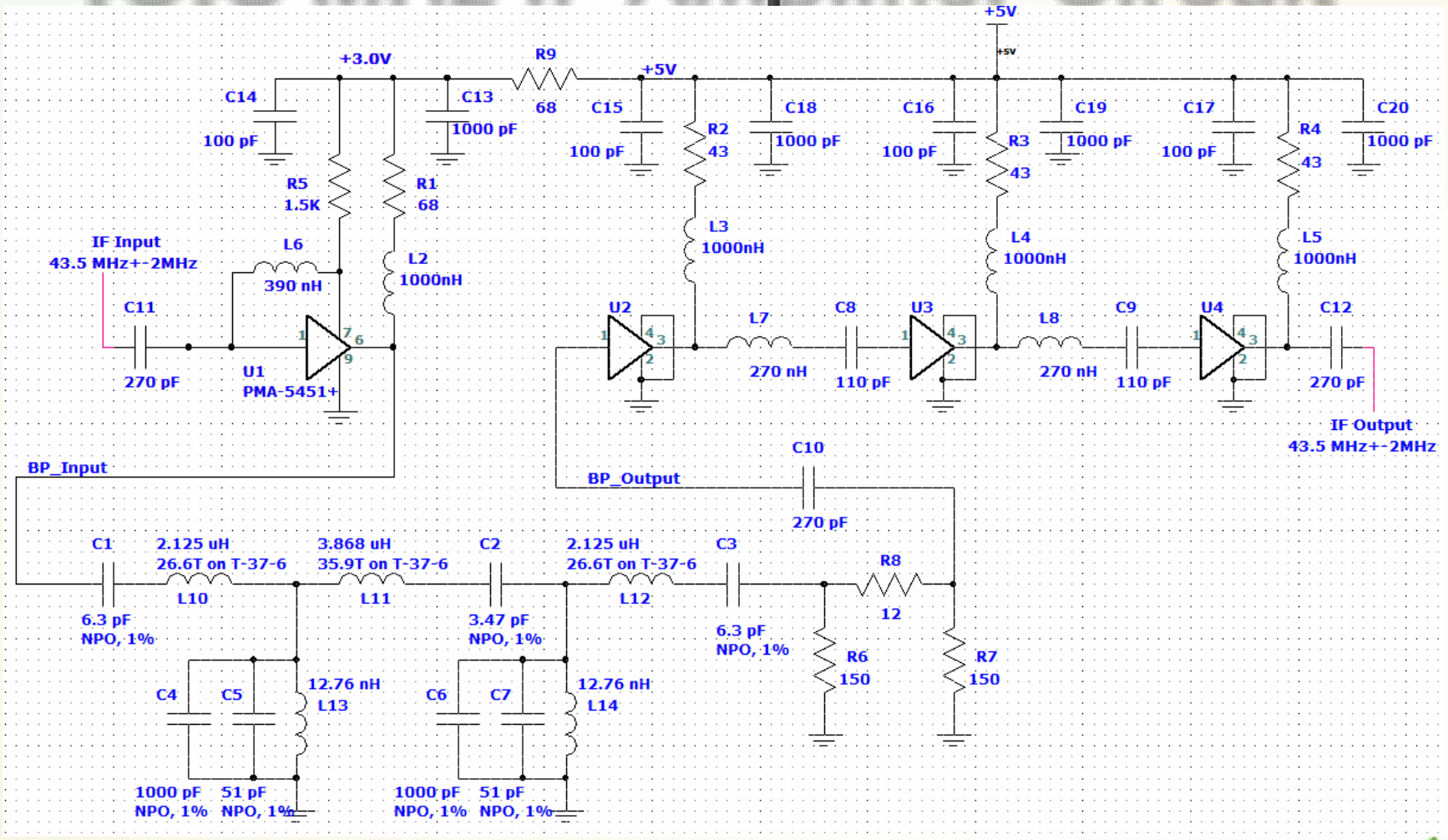
IF Frequency/Phase Response



IF Amplifier Design

- Uses Mini-Circuits active components:
  - PMA-5451+ amp for IF input
  - LEE-39+ for broadband
- Vendor S-parameter files for these parts were used with *Linc2.*
- Swept S-parameter file created by *Linc2* for the bandpass filter was incorporated as an external block ‘component’.
- Component Q and losses were considered for all critical LCs.

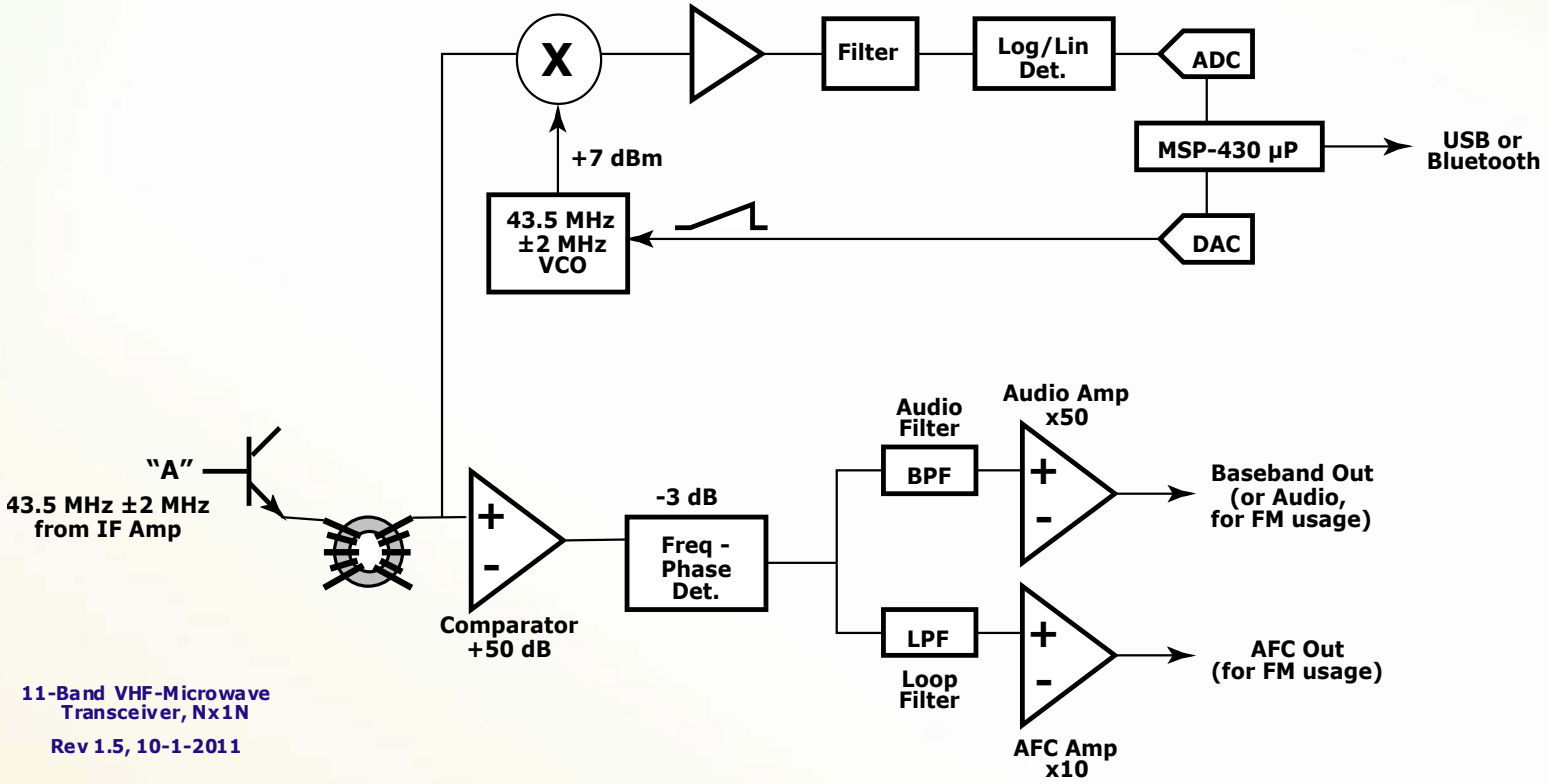
43.5 MHz IF Amplifier Circuit



Planned (non-SDR) Baseband Stuff

- Combine with the IF module as a wide-bandwidth panadapter or spectrum analyzer.
- Use the IF module as for the IF of an FM communications link, supporting:
  - Voice
  - Digital Internet connections (RJ45 in/out)

Planned (non-SDR) Baseband Stuff



Schematic and Layout Tools

- Currently using Advanced Circuit's free *PCB Artist*. Lowest PCB cost
- Have but no longer use the more superior free PCB-123 software. Much-increased prices made that decision. This package is superior in almost every aspect to *PCB Artist*, but the boards can be almost double the cost in any volume.

Conclusions

- This has been a learning/stretching experience.
- The use of RF design tools makes all the difference. They were worth the 5-6 days of frustration in learning them.
- The tools instilled confidence in the outcome, overcoming personal fears about the result.

Conclusions

- Completion of a set of mix-and-match modules is a worthwhile and achievable goal.
- Assembly and use of modules from a kit has the makings of a good club project.
- The design is less difficult than imagined.
- Others who have ‘been there’ make for good peer review.
- Doing something different from the status quo is a healthy thing.

Next Steps

- Lay out and debug the IF Module
- Design the VCO for the top LO
  - Incorporate some very-patentable noise reduction stuff.
- Finish the layout for the 11-band divider and reference chain.
- Lash up a uP, probably a TI MPS-F430, to control the IIC dividers and, RF switches and T/R logic.
- Finish the 5.76/10.368 MHz RF frontends.

Interested in Following?

- If you are interested in following the progress of *Antelope*, you can do two things:
  - Join the *RoadRunners Microwave Group* email reflector. Send an email to *rmg@k5rmg.com* requesting to be added. It will bounce but the webmaster will add you. Progress notes are added there (usually) on Fridays.
  - Join the antelope@itoric.com group by sending an email to thomas@itoric.com, requesting your addition.

Questions/Comments?

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