LNA Options for SKAMP

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There are two main options for the LNA position in the SKA Molonglo Prototype (SKAMP).

Option 1: One LNA for each feed antenna element with the signal combining and beam steering after the LNA. This equates to many thousands of LNAs, which would have to be very cheap, given the budgetary constraints. Losses in the signal combining and beam steering would then be unimportant provided the LNAs have sufficient gain. Gain would need to be at least 30 dB, provided that the noise figure of the rest of the receiving system was not too high.

Option 2: Do the signal combining and beam steering before the LNA and so reduce the number of LNAs. These could then cost more and maybe have lower noise than for option 1. Losses in the signal combining and beam steering will add directly to the LNA noise temperature. It is doubtful that these losses could be less than 0.3 dB, which is around 20 K. The input noise temperature would then be 45 to 50 K minimum.

LNA Types

Option 1

For option 1 the LNA would need to use off the shelf items such as the MINI-CIRCUITS MARn range of monolithic amplifiers. These are well matched 50 ohm input/output devices but the noise temperature is around 260 K for the lowest noise wideband device. Cost of these monolithic amplifiers is from US$1 upwards. There are some lower noise MINI-CIRCUITS monolithic amplifiers with noise around 120 K, but these cost US$200 each and have limited bandwidth. A two-stage amplifier will probably be needed given that the gain is generally in the range of 15 to 20 dB for a single stage.

There are other monolithic amplifiers intended for mobile phones in the 1900 and 900 MHz bands that have noise temperatures of the order of 70 K. However the matching is poor outside their nominal frequency band and the gain is not very flat over a 300 to 1500 MHz bandwidth.

MAXIM makes an amplifier, a MAX2640 for the 900 MHz band, which has a noise of 70 K. I have modelled a single stage amplifier on PUFF (file MAX2640B.PUF) It has 15 dB gain that is reasonably flat across the band using some additional matching components but the input matching is poor, Varying between 1.4 and 6.2 dB return loss.

Another amplifier is the BGA622. Infineon developed this but the product line has been sold to Vishay. (I have been unable to get any pricing from the Australian agents Avnet, because of this). A two-stage amplifier has been modelled on PUFF (file BGA622E.PUF). The gain of 37 dB is quite flat over the 500 to 1400 MHz range and the input matching is better than the MAX2640, with a range of 3.6 to 11 db return loss. Output matching is good. Noise of the device is given at 75 K at 1.4 GHz down to 65 K at 300 MHz in the data sheets. The BGA622 is characterised for the 1.9 to 2.4 GHz band and has internal frequency sensitive components, which makes for poor input matching at low frequencies. Power requirements are low ... 2.8 v at 6 mA.

Both of these amplifiers use Si-Ge technology and like all BJTs the gain drops with increasing temperature. A 0.6 dB gain drop over a 0 to 50 C temperature range is typical.

The BFP620 device mentioned in the past by John Bunton is just a Si-Ge transistor that needs a biasing circuit and input/output matching to make an amplifier. The device noise figure from the data sheet is 0.7 dB (51 K) at 1.8 GHz with Ic of 5 mA.

There is no reason to expect that lower noise temperatures will available in the future for amplifiers intended for terrestrial communications. It is system noise temperature that determines signal to noise ratio. System noise temperature is the sum of antenna temperature, LNA temperature, the equivalent temperature for loss between antenna and LNA, and the following stage contribution. (Following stage contribution is minimised by having sufficient gain in the LNA.) For terrestrial communications the antenna temperature is 300 K, so reducing amplifier noise figure by 1 dB gives just a 1 dB increase in signal to noise ratio. This applies equally if the drop is from 10 to 9 dB or 1 to 0 dB. It is easier and cheaper to improve the antenna or raise the transmitter power to increase the S/N ratio by 1 db. In other words there is just no driver to decrease amplifier noise for terrestrial communication systems. It is about as low as it will ever be unless some new technology comes along, which for some other reason, just happens to give lower noise figures.

For space communications or radio astronomy the antenna Te can be as low as 20 K, so reducing amplifier noise figure gives a greater improvement in the S/N ratio. For example, a system Te drop from 100 to 50 K gives a 3 dB improvement in the S/N ratio.

Option 2

A wide band, custom made, two-stage HEMT amplifier is needed for this option. I have modelled such an amplifier on PUFF (file 4316LNAS.PUF) and built it. The input bandwidth is achieved using a series of L matching sections. The interstage match has 2 L sections. Loss in the input circuit adds to the device noise temperature so that the expected noise amplifier temperature would be 25 to 30 K minimum. Adding the signal combining and beam steering loss brings the input noise temperature to the 45-50 K range. This is 20 K less than the BGA622 device although there would be some input circuit loss to be added for the option 1 case. The 25-30 K temperature is only achievable with air wound coils in the input circuit, which are unsuitable for mass production of the 1000 or so LNAs required for this option. Small chip surface mount inductors have a measured loss at 450 MHz of 0.1 dB each. Five are needed for the input matching which raises the LNA noise temperature to be close to that of the BGA622. I have searched the web for surface mount coils and haven't found any that are significantly better than the ones from the Infineon SM coil kit that have been tried in a LNA.

The HEMTs that have been used for the 843 MHz LNAs and the ATNF 700 MHz LNA are intended for 12 GHz satellite TV LNAs. At frequencies below 5 GHz or so they are unstable and need RF absorber blocks and clever circuit design to make them stable. The HEMTs used in the 843 MHz LNA are now obsolete and their noise temperature is 2 to 7 K higher than the newer MGF4953A devices from Mitsubishi (in the 300 to 1500 MHz range). However they are more stable at low frequencies than the MGF4953A, which oscillates readily at 15 GHz. Agilent (formerly Hewlett Packard) have a range of HEMTs in a SOT-343 package, which have a gate width of 400 to 1600 micrometres? (nanometres). These devices are intended to be used in the 900 to 2000 MHz range and could be more stable than the MGF4953A. The Fmin of the ATF-35143 is given as 0.11 dB at 500 MHz but this value has been extrapolated from measurements at 2 GHz and higher. A 1600 MHz amplifier on a demonstration board with chip inductors had a NF of 0.85 dB (or 63 K). The ATF-35143 costs AU$1.66 for 10,000 quantities, $1.74 in quantities of 100. The wideband LNA (4316LNAS.PUF) will need to be reworked for the Agilent HEMTs because the scattering parameters are quite different. I have asked Avnet, the Australian agent for samples of the ATF-35143 HEMT and the BFP620. (These come from the manufacturer via Avnet, not Avnet themselves.)

Other Comments

It may be worthwhile trying the BFP620 which costs AU$0.70 in quantities of 10,000 for a low cost LNA for option 1. One other possibility, seeing that some 25,000 devices will be needed for option 1, is to ask the manufacturers of the BGA622 if they could make a version more suitable for our frequency range. It would be nice to make an LNA with MMICs such as the BGA622 because tuning would be unnecessary and only a few (around 10) extra surface mount parts would be needed. This is probably the only way a $10 LNA could be made. Using the BFP620 or BGA622 would halve the supply current compared to HEMTs and probably not need a negative supply rail. Having the LNA before beam steering and combining networks would reduce the cost of making these networks and probably their size. That is they could be made on cheap FRP4 circuit board.

Conclusion

Given the budgetary constraints the 50 K system noise temperature mentioned in the outline paper is very optimistic. It is likely to be nearer to 100 K in the end. With unlimited funds the 50 K figure could be achieved with a custom made 25 K LNA for each antenna element and beam steering / combining after the LNAs. The MOST antenna would also have to be resurfaced to reduce ground noise and low sidelobe feeds employed to achieve 50 K. If a 70 K LNA could be made for under $10 it may allow more of the MOST antenna to be used, thereby offsetting the higher noise temperature.

I have shown that a custom made 300 to 1400 MHz LNA using 12 GHz HEMTs can be made, but simultaneously achieving low noise, good wideband input matching, flat amplitude response and circuit stability (freedom from microwave oscillation), is a difficult task, one that will not be done overnight.

The Numbers

OPTION	LNA type	LNA Te K	Antenna Te K	Balun Te K	Input loss Te K	Following stages K	Total system K
1	custom (air coils)	25	25	7	0	3	60
1	custom SMD coil	45	25	7	0	3	80
1	BGA622 MAX2640	80	25	7	0	3	115
2	custom (air coils)	25	25	7	20	3	80
2	custom SMD coil	45	25	7	20	3	100