The Impact of High Power Amplifiers and their associated Lowpass-Filters on Pseudorange Accuracy and the Spectrum of the Signal[1]

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Introduction

Any broadcasting satellite needs a component to raise signal power to the desired level to fulfill link budget requirements. Usually this is performed by a so called High Power Amplifier (HPA).
Two well-known subtypes of HPA are currently in use:

- **Traveling Wave Tube Amplifier (TWTA)**
  This classical type of HPA is still used for most applications requiring power levels of 50 Watts and above.
- **Solid State Power Amplifier (SSPA)**
  The recently available SSPA is used for applications with less power demand.

Due to their physical principles these two subtypes of HPAs have nonlinear amplification characteristics. Since a signal that is transmitted over a non-linearity experiences a spreading in frequency domain usually the bandwidth of the amplified signal is increased.
To fulfill spectral reglementations required by authorities bandlimitation has to be applied. This is performed by a lowpass Filter.
A simplified signal processing chain of a typical navigation satellite can be depicted as in the following block-diagram (Figure 1).

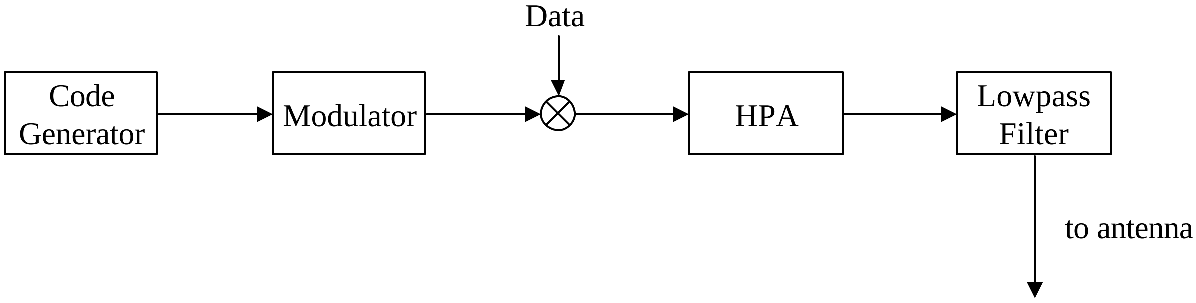

Figure 1 Simplified Block Diagram navigation signal generation

For a navigation system the major question is to figure out the impact of these nonlinearities and bandlimitations on bandwidth and navigation accuracy. Some simulations results are presented in the following.

[1] This Work was supported in the frame of the Signal Design and Performance Study by the European Space Agency (ESA) see [SDS98].
[2] R. Schweikert and T. Wörz were with DLR when this work was carried out and are now with: AUDENS ACT Consulting GmbH, P.O. Box 1110,D-82224 Seefeld

Background – HPA Characteristics

For our simulations we selected two typical examples of HPAs. Their measured characteristics are depicted in Figure 2 and Figure 3.

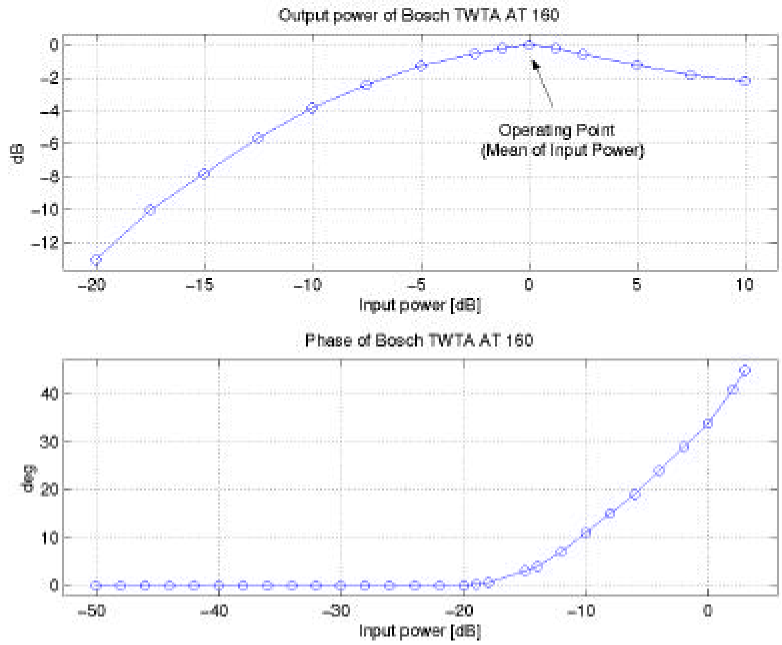

Figure 2 Characteristic of Travelling Wave Tube Amplifier

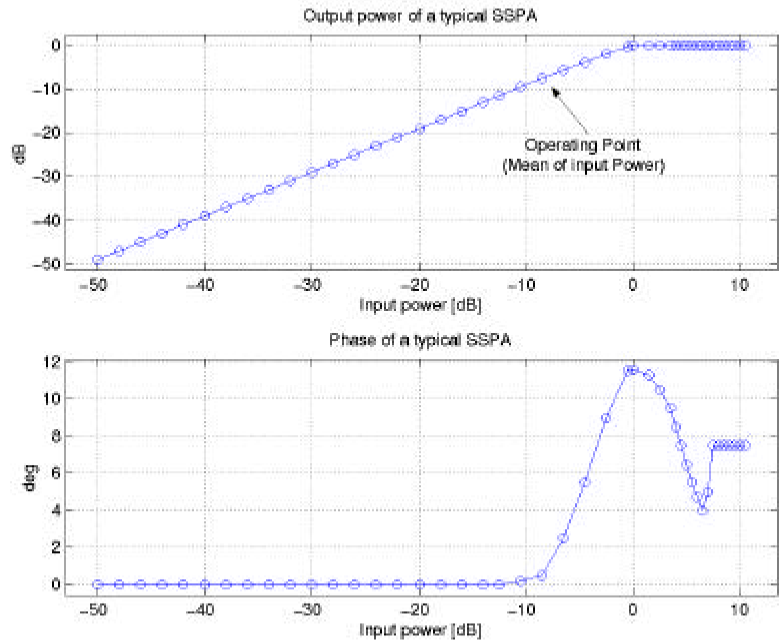

Figure 3 Characteristic of Solid State Power Amplifier

Since a future European Global Navigation Satellite System has serious restrictions on available bandwidth the focus of our work was in investigating bandwidth-efficient modulation schemes [EC99]. What is presented here, are results for 4-PSK square-root-raised-cosine (SRC) pulse-shaping. The selected rolloff-factor was 0.2. To heve comparable simulation results a standard DLL-receiver (B_L=2Hz) was selected for simulations [PAR96].

Simulation Results

Looking at the characteristics of the HPA and there distinctive distortion as well in amplitude and in phase, one might expect very severe degradation of navigation accuracy. Surprisingly that is not the case. Figure 4 shows that there is nearly no perceptible degradation on the pseudorange estimation.

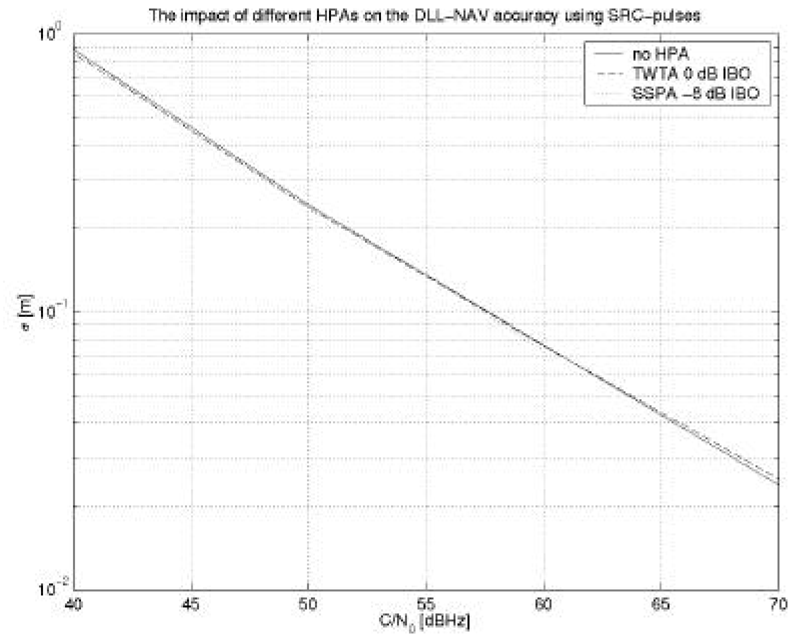

Figure 4 Pseudorange accuracy resulting of different HPAs

Obviously there must be an effect on the spectrum of the transmitted signal. From a theorectical point of view there must be spectral broadening. Our simulation result is shown in Figure 5. It can be seen, that the nonlinearities enlarge the signal spectrum seriously. Due to the previously mentioned regulatory aspect this is not acceptable.
Therefore lowpass filtering must be applied.

For an intended high-accuracy delay estimation it is clear that filters showing high group delay variations in the passband are to be avoided. Therefore we selected Butterworth and Tchebycheff filters as candidates, since both have less variations in group delay than e.g. an elliptic (Kaiser) filter.

The result of the simulation with different lowpass filters compared to the non-filtered and non-amplified performance are shown in Figure 6. The standard deviation increases significantly due to filtering. This is surprising but in [WEI94] Bandwidth is identified as a very important feature of the signal format.

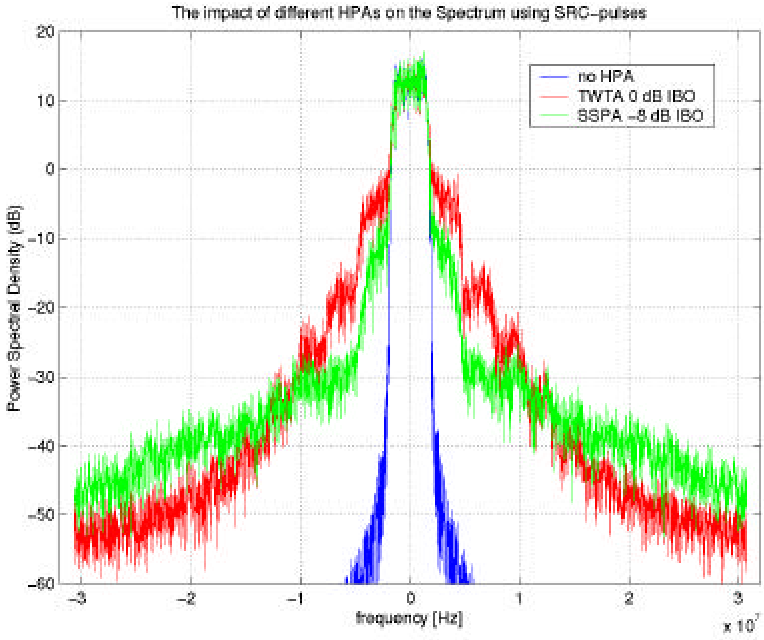

Figure 5 Spectra resulting from HPA nonlinearities

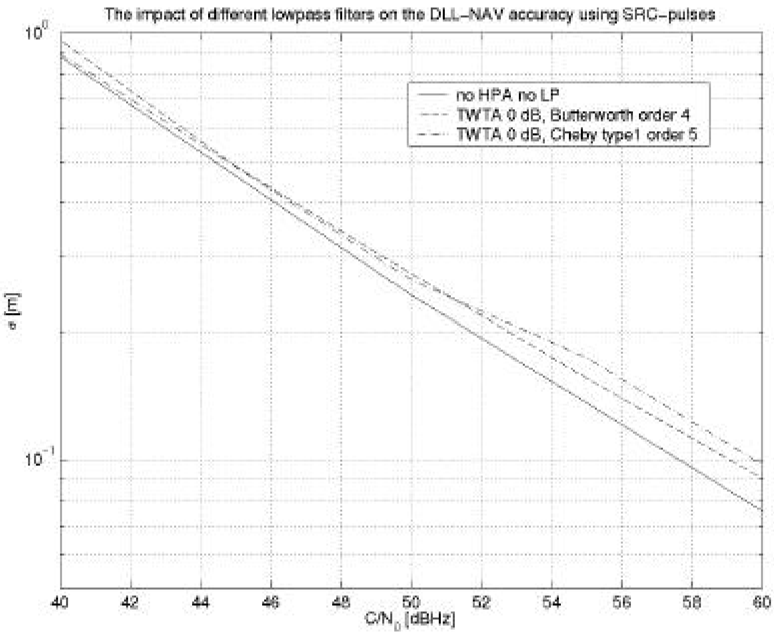

Figure 6 Pseudorange accuracy resulting from lowpass-filtering

Now we can see that the filtering does have a negative influence on the accuracy of pseudorange estimation.

Dimensioning HPAs and lowpasses

There are two Strategies for dimensioning the system:

1. **High IBO strategy**
   In this strategy the IBO is selected near 0dB. The result is a maximal distorted Signal which has no effect on the navigation accuracy. Due to the lage banwidth used Filtering with high order lowpass filters is required. This filtering will decrease the navigation accuracy about –1dB. This strategy will result in a good power efficiency but the navigation accuracy of the over all system will decrease when the IBO is selected too high.

2. **Low IBO strategy**
   In this case the IBO is selected as low as possible. Due to the lower distortion a lower degree lowpass filter can be used. Which causes lower degradation of the navigation accuracy. In terms of power efficiency versus navigation accuracy this approach is less effective due to the low power efficiency of the HPA.

3. **Combined design strategy**
   In order to maximize the power efficiency of the HPA at the one hand and minimizing the navigation error on the other hand a combined design strategy will be the matter of choice. In many cases the best compromise is near –1dB.

Future Work

Currently we are in Research for other Signal Formats such as BPSK with rectangular pulses (as used in GPS).

Conclusions

Obviously there is no effect from the distortion of the navigation signal by HPAs. Though the degradation caused by filtering is remarkable. Therefore system designer should focus attention on filtering issues rather than on distortions by nonlinearities. Respectively HPAs and Filters have to be treated as one unit and must be dimensioned together.

Bibliography

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[WEI94] Lawrence Weill: „C/A Code Pseudoranging Accuracy - How Good Can It Get?",