The Big Challenge:
Improve Sensitivity of GPS Receiver in Simultaneous GPS Operation

White Paper

By: ChewEan Tan and Allen Wong

Introduction

S-GPS (Simultaneous Global Positioning System) is an operation where the reception of GPS signal and the transmission of voice or data signal from the handset, happen at the same time. The interferer signal from the voice or data transmission may leak to the GPS receiver's path and affect the receiver's sensitivity by overloading the receiver's low noise amplifier or the receiver's backend.

This creates a big challenge to the handset designers. The designers need to maintain the sensitivity of the GPS receiver for the weak incoming GPS signal while there is a strong interferer signal from the transmitting voice or data. This requires a GPS receiver front end with low noise figure and high gain for the weak GPS signal while, meantime, provide very good blocking to the strong interferer signal.

Integration of Low Insertion Loss High Blocking Capability FBAR Filter to Low Noise Amplifier

This can be achieved by placing a pre-filter to block the strong interferer signal from leak into the GPS receiver path. According to Friis equation, the noise figure or the insertion loss of the first stage will be the dominant to the noise figure of the receiver chain, providing the following stages has reasonable gain. Thus, an integration of filter with low insertion loss, high out of band rejection and an amplifier with low noise, high gain and good linearity play the main role to achieve the objectives mentioned in the previous paragraph.

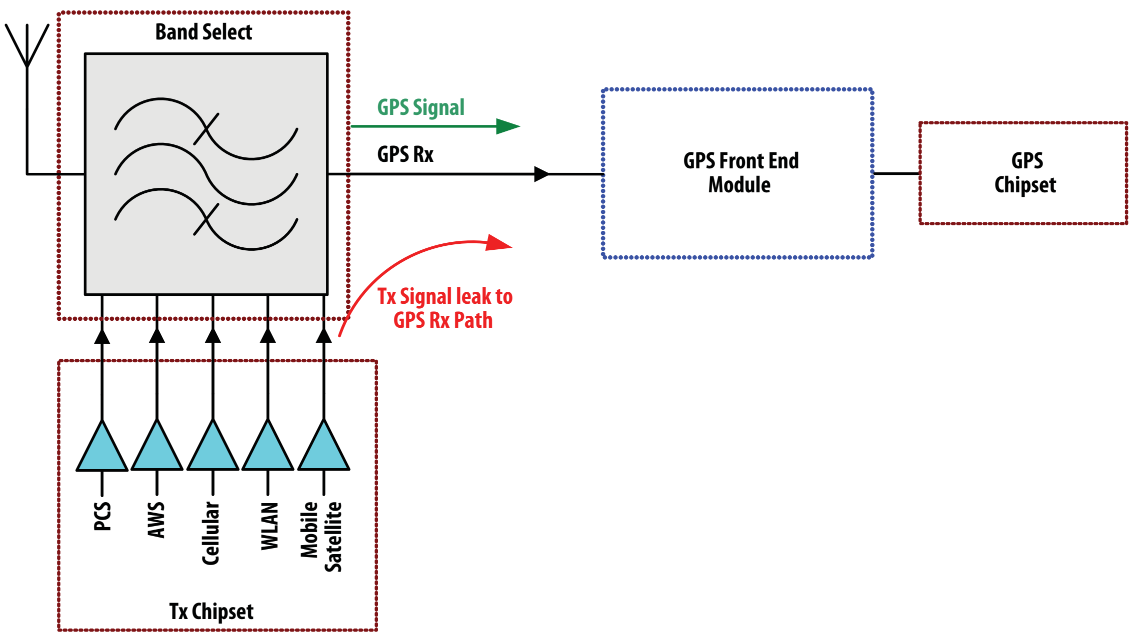


Figure 1. Rx Front End Simplified Block Diagram

Avago Technologies' GPS front end module consists of FBAR filter and GaAs E-pHEMT (Enhancement-mode pseudomorphic high electron mobility transistor) low noise amplifier. FBAR is a breakthrough resonator technology developed by Avago Technologies. This technology produces small size filters with excellent Q. The excellent Q translates into a very steep filter roll-off or superb out-of-band rejection. With the integrated filter, the module achieved exceptional out-of-band rejections to the interferer signal. This characteristic is essential to filter out all the interference signals which are close to the GPS signal at 1.575 GHz while maintain the low noise figure of the amplifier. For example, satellite telephone communication band is using 1.62 GHz signal which is very close to GPS frequency. Thus, it require a filter with steep roll-off to block the 1.62 GHz signal while doesn't attenuate the in band GPS signal significantly.

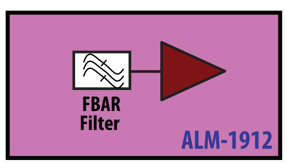
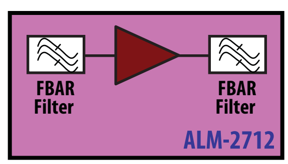
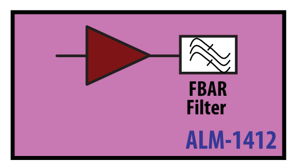
Since the noise figure is always dominant by the first stage of a receiver path, the integration of the low insertion loss FBAR filter as the first stage of the module follow by the GaAs low noise amplifier produces a GPS amplifier module with very low noise figure and high out of band blocking capability.

RF Performance

Table 1 summarizes the RF performance of a few Avago Technologies' GPS modules with various pre-filter, post-filter and amplifier combinations. Both the ALM-1912 and ALM-2712 are with FBAR filter as the first stage follow by a low noise amplifier. ALM-2712 has an additional post filter compare to ALM-1912. ALM-1412 is a combination of low noise amplifier follow by the post filter.

Referring to table 1, ALM-1912 and ALM-2712 show significant better blocking capability to the interferer signal. The out-of-band input P1dB of ALM-1912 and ALM-2712 at Cellular band, PCS band and WiFi band is far better than ALM-1412 which doesn't have a filter before the LNA. The high out-of-band P1dB shows that the module is able to operate at the presence of strong interferer signal without saturate the amplifier.

Table 1. RF Performance and simplified block diagram of GPS modules.

	Unit	ALM-1912	ALM-2712	ALM-1412
GPS LNA Module				
Noise Figure	dB	1.6	1.25	0.8
Gain	dB	19.3	14.2	13.5
IIP3	dBm	+1.5	+5	+7
Input P1dB	dBm	-8	+2	+2.7
Input P1dB (Cellular Band)	dBm	+39	+21	-6
Input P1dB (PCS Band)	dBm	+44	+37	-6
Input P1dB (WiFi Band)	dBm	+43	+35	–

Measurement and Test Setup

Another measurement is made to compare the blocking capabilities of the 3 modules to the presence of interferer signal. The measurement is made by monitoring the degradation of the module's noise figure with the presence of interferer signal at certain power level. In this measurement, the frequency of the interferer signal is at 1.62 GHz, which is close to the GPS frequency and may bring most significant effect to the GPS frequency noise figure. Figure 2 illustrates the test setup of the measurement.

A CW signal at the interferer frequency (Jamming Signal/ Interferer Signal) is generate by a signal generator. The interferer signal and the noise source are combined together using a power combiner and been feed to the GPS module to measure the modules' noise figure.

The interferer signal is amplify by an external pre-amplifier to boost up the power level of the signal before the interferer signal is combined with the noise source. The noise figure analyzer is able to measure or receive signal at very low noise floor. Thus, any additional noise from the interferer source is significant and will be included in the noise figure measurement. An interferer source with high noise floor at the GPS frequency may end up cause a measurement on the noise floor of the interferer source instead of measuring the modules' noise figure. In order to make sure there is no additional noise floor been included in the noise figure measurement, the interferer signal is attenuate by filters at GPS frequency in order to suppress the signal/noise at this frequency.

As discussed in previous paragraph, it is essential to have a high rejection to the noise floor of interferer signal at GPS frequency to have proper and accurate measurement for this test. Referring to Figure 2, a bandpass filter is placed at the interferer signal source to filter the harmonics of the interferer signal. Besides, there are two notch filters been placed after the bandpass filter, to suppress the noise floor of the interferer signal at GPS frequency. Figure 3 shows the frequency response of the 2 cascaded notch filters and a bandpass filter. The cascaded filters give attenuation of 100dB at 1.575 GHz and low loss at the interferer signal frequency of 1.62 GHz.

For the test setup after the DUT (Device Under Test)/GPS module, a GPS bandpass filter is placed before the noise figure analyzer to block the strong interferer signal from entering the noise figure analyzer. This helps to avoid the analyzer from being overloaded by the strong interferer signal.

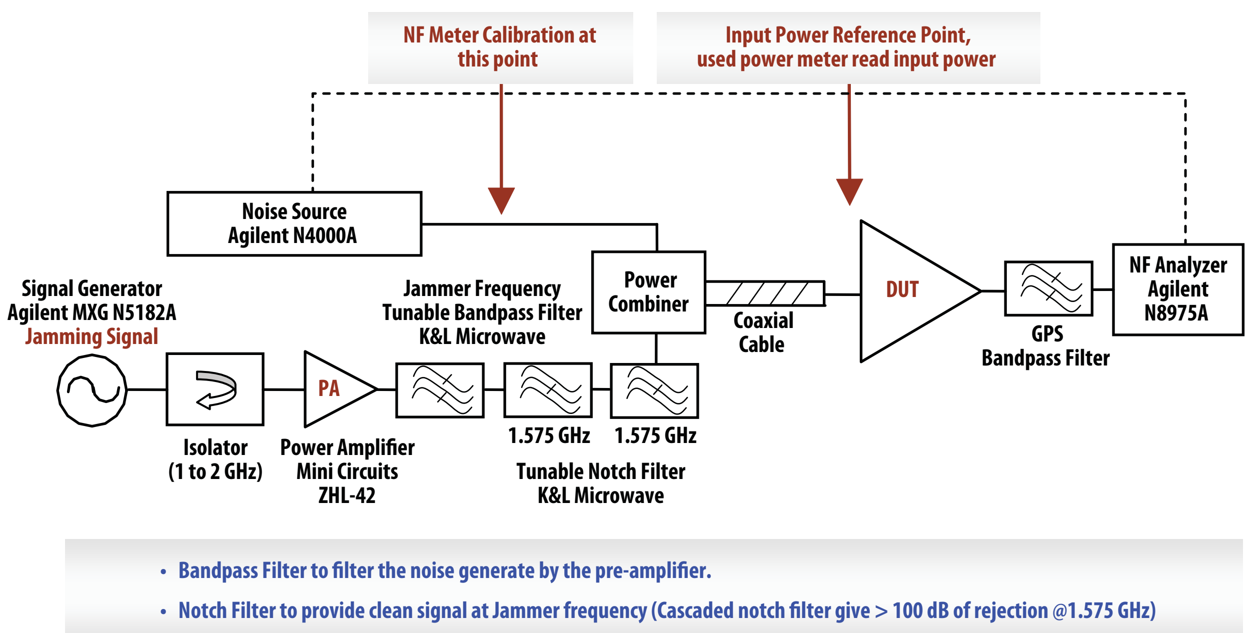


Figure 2. Test Setup for Noise Figure Degradation with Presence of Jamming Signal.

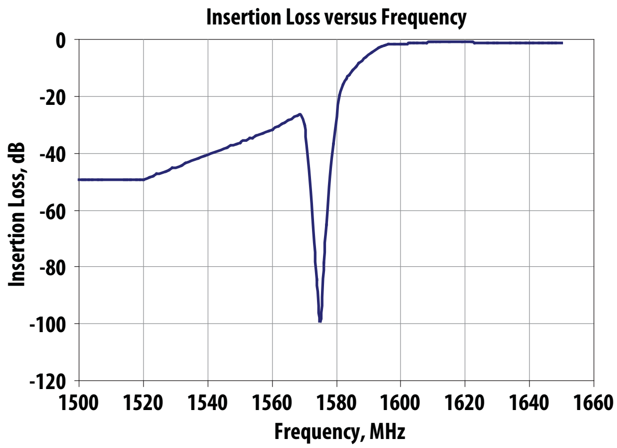


Figure 3. Filter Response For Cascaded Notch Filters and Bandpass Filter

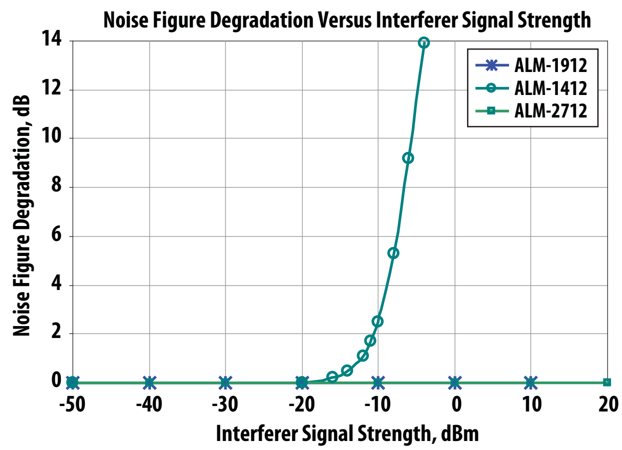


Figure 4. Noise Figure Degradation versus Interferer Signal Strength.

Discussion and Measurement Result

Figure 4 shows the degradation of the modules' noise figure at the presence of strong interferer/jamming signal at 1.62 GHz. The degradation is with reference to the modules' noise figure when there is no interferer/jamming signal. The result is measure based on the test setup illustrated in Figure 2.

ALM-1412 without the pre filter as the first stage, the noise figure is degrade by >1 dB before the interferer signal reach the power level of -10 dBm. Both the ALM-1912 and ALM-2712 do not show degradation on the noise figure with the power level of interferer signal as strong as 20 dBm.

Evidently, GPS module with pre filter has a better rejection towards strong interferer signal. In this example, the measured data shows that ALM-1912 and ALM-2712 with pre filter has better robustness with the presence of strong interferer signal compare to ALM-1412 which without pre filter before the amplifier.

Summary

In summary, with the integration of FBAR filter as the first stage will serve a better robustness on the noise figure performance against the interference signals, due to it's excellent out of band rejection. The low insertion loss of the FBAR filter is bringing a minimum degradation to the noise figure of the amplifier as well. As the result, GPS amplifier module with a low insertion loss and high out of band rejection FBAR pre filter is a good solution for GPS receiver chain. In addition, the integration of all the components into a small module package reducing the board space needed and reduced the design turn around time.

References

- "GPS Antenna LNA', by D.Orban and T.Eyerman
- Application Note AN-5240: "ALM-1106 as a 1.575 GHz GPS Low Noise Amplifier"
- "Improving S-GPS sensitivity" by Allen Chien and Won Kyu Kim (http://www2.electronicproducts.com/Improving_S-GPS_sensitivity-article-farr_avago_jun2008-html.aspx)

AV02-3011EN - September 20, 2011