Integrating a Limiter/Filter/Amplifier into a Conformal Wraparound GPS/TM Antenna Substrate

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ABSTRACT

Missile instrumentation systems designers are constantly striving to achieve better performance out of their systems. Optimizing the antenna coverage and decreasing the noise figure are constantly strived for in order to improve system performance. At the same time, weapon systems are becoming smaller with the resulting reduced area for instrumentation. One way to achieve a lower system noise figure is to have the limiter, filter, and amplifier (LFA) located as close to the antenna as possible. This can be achieved by integrating the LFA into the substrate of a conformal wraparound antenna. Not only does this decrease the system noise, but it also saves space in an already crowded missile instrumentation section. This paper details the latest efforts in accomplishing this integration.

KEY WORDS

Microstrip, antenna, low noise, GPS, telemetry, wrap-around, filter, amplifier

INTRODUCTION

In fiscal year 1999 (FY99), the NAVAIR, Naval Air Warfare Center, Weapons Division (NAWC-WD) started the development of an integrated Global Positioning System (GPS) and Telemetry (TM) Antenna System to fit on small diameter missiles. The Multi-Band Antennas for Telemetry (MuBAT) Program was a Central Test and Evaluation Investment Program (CTEIP) that was funded by the Office of Secretary of Defense (OSD). It was a three-year, tri-service (Army, Navy, and Air Force) effort with the goal of developing antennas for air-launched munition testing that supported telemetry, GPS, and flight termination needs. It also strived to provide quality antennas for unusual geometries (e.g. small and narrow missiles, tank rounds...). A paper [1] has previously been presented detailing the milestones achieved with this Program. Due to the successful completion of the Program one of the outcomes is that NAWC-WD now possesses the capability of integrating a LFA and filter into a wraparound antenna substrate. As a result, several other missile programs have requested this design be incorporated into their antenna systems. The latest effort including design specifications and typical test results are detailed in the sections to follow.

ANTENNA DESIGN PROCESS

Specifications

Below are typical specifications for the GPS and TM Antennas. They are required to be cylindrical and fit flush-mounted onto a missile with a diameter typically between 2.0 inch and 14.0 inches. The axial length ranges from typically 2 to 4 inches with a thickness in the 0.04 to 0.25 inch range. The wraparound antennas are usually comprised of three boards, etched as a standard flat printed circuit board (PCB) and then laminated together under high temperature and pressure on a cylindrical bonding fixture using bonding film. The outer board is the protective cover and is made from RT/Duroid 5870 dielectric material [2]. The next board contains the antenna radiating elements and the third board the feed network, filters, limiter, and amplifier. Because of the sensitivity of the antenna element's frequency to temperature change, the bottom two boards are usually RT/Duroid 6002 dielectric material [2], an ultra stable material versus temperature. The cover board has been between 0 and 0.062 inch thick and the antenna and feed network boards between 0.02 and 0.12 inch thick. Besides the obvious requirement of a filter in the GPS antenna to protect the amplifier from being saturated by the TM signal, the filter in the TM antenna is required to lower the noise in the TM transmitter at the GPS frequency so that this noise does not degrade the signal to noise ratio.

The electrical design specifications of the GPS antenna are:

Center frequency:	1572.5 MHz (L1 Band)
Bandwidth:	$\pm$ 10 MHz
Polarization:	Right Hand Circular
Filter:	-50 dB minimum isolation in TM frequency band
Amplifier:	26 dB minimum gain and 1.2 dB maximum noise figure

The electrical design specifications of the TM antenna are:

Center frequency:	2250 MHz (S Band)
Bandwidth:	$\pm$ 25 MHz
Polarization:	Linear
Filter:	-50 dB minimum isolation in GPS frequency band

Antenna Design

Several Software Packages are used in the design of the antenna systems. "Ansoft Designer" and "HFSS" [3] are used in the antenna element design. "Eagleware" [4] is used for the feed network and filter design and the PCB layout of the items for the feed network boards. Orcad Layout [5] is used to do the PCB layout of the antenna board and the rest of the feed network board.

FILTER AND AMPLIFIER COUPON DESIGN

In order to increase the link margin of a GPS system, either the antenna gain has to be increased or the noise figure of the receiver needs to be lowered. For an application where quasi-omni coverage is desired, the antenna gain is limited. The only option is to minimize the noise figure and minimizing the

cable loss between the antenna and the Low Noise Amplifier (LNA) can do this. This can be accomplished by integrating the LNA into the antenna system substrate. The gain of the LNA is typically in the 20 dB or greater range so that noise figures contributions after the LNA to the total system is negligible. A filter is required before the LNA to reject the strong TM signal, usually from an antenna in close proximity to the GPS antenna, so that the signal does not saturate the LNA. The filter used is a Band Stop Filter and was designed using the "Eagleware" Software Package and incorporated into the antenna feed network. The out of band rejection is in the range of 40 dB minimum. An Schottky diode is used as a limiter to prevent power spikes from damaging the GPS Receiver. The LNA used is the M/A-COM's AM50-0002 with a specification of 1.15 dB noise figure, 27 dB gain, and 3 to 5 volt bias at 20 ma. An added advantage of this amplifier is that DC blocking or bias bypass capacitors are not required and a grounded transmission line is used to match the amplifier input making it much less susceptible to high power damage. The amplifier is in a SOIC 8-lead surface mount plastic package that makes it inexpensive and small enough to fit in one of the antenna's dielectric board layers. A photograph of the test coupon used to test the amplifier and limiter and limiter alone is shown in Figure 1.

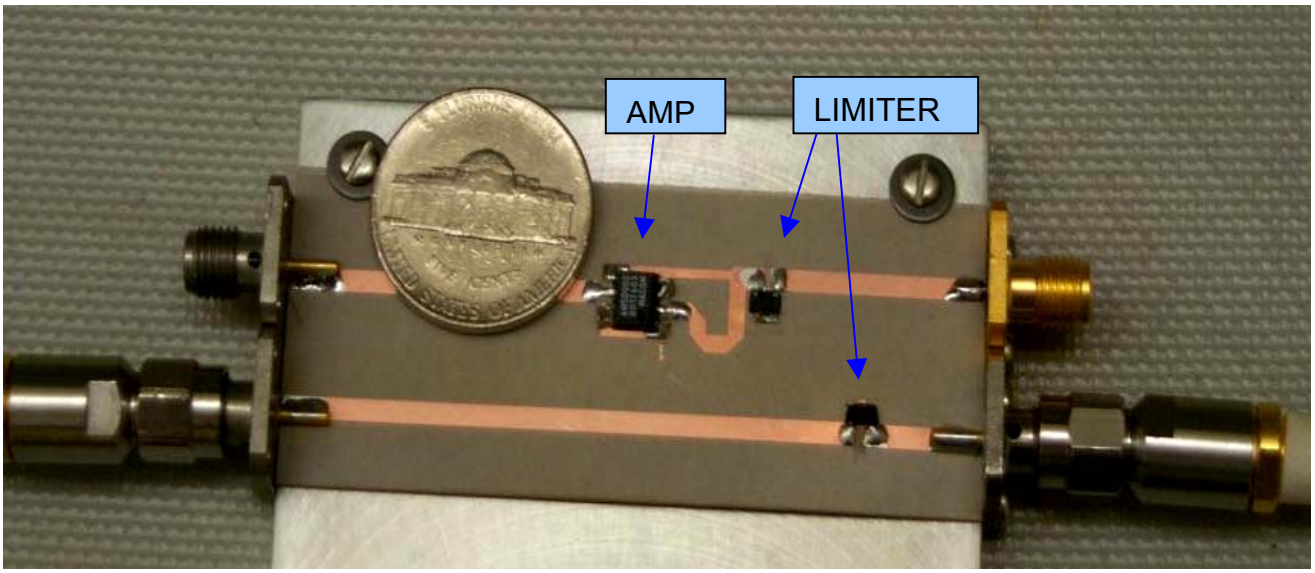

Figure 1. Limiter and LNA test coupon.

TEST RESULTS

Typical test results are shown here indicative of what has been achieved in integrating the filter, limiter, and LNA into the antenna. Figure 2 is the gain measured on the limiter/amplifier shown in Figure 1. The noise figure was measured and was 1 dB at 5 volts bias and 1.2 dB at 3 volts. The totally integrated antenna system with TM and GPS achieved the desired isolation between antennas as shown in Figure 3 where the isolation exceeds the 50 dB specification.

The radiation patterns are shown in Figure 4 for both the GPS, vertical and horizontal polarization, and TM, copolarization, for

roll, pitch, and yaw.

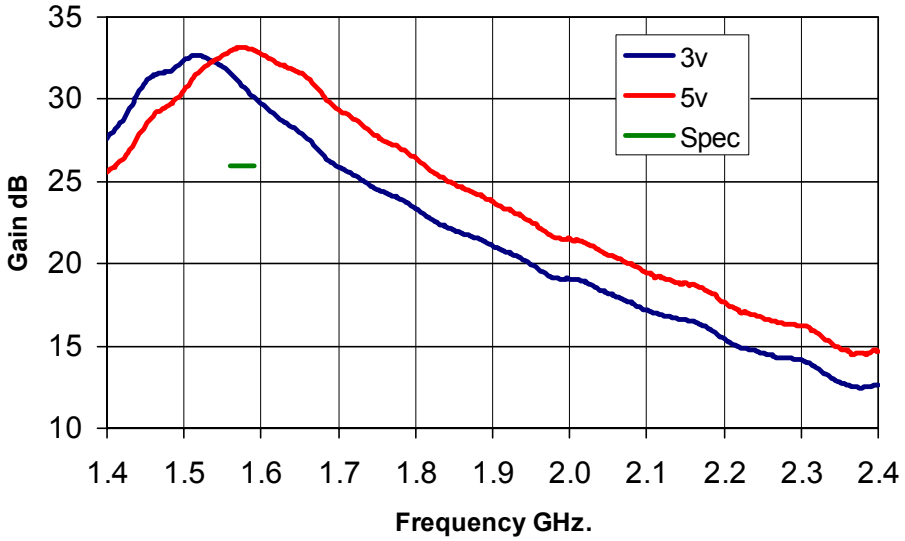

Figure 2. Limiter and LNA test coupon.

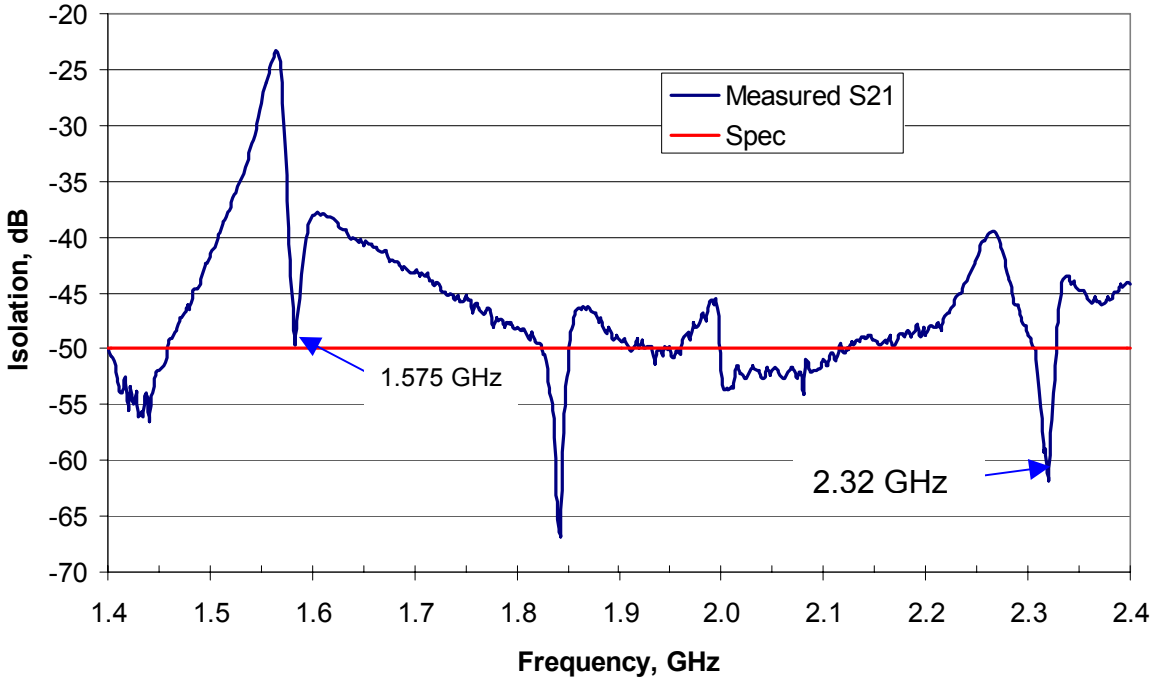

Figure 3. GPS to TM Isolation test data.

CURRENT DESIGN CHALLENGE

The filters are now a requirement on all antennas and the limiter and amplifiers have been used on

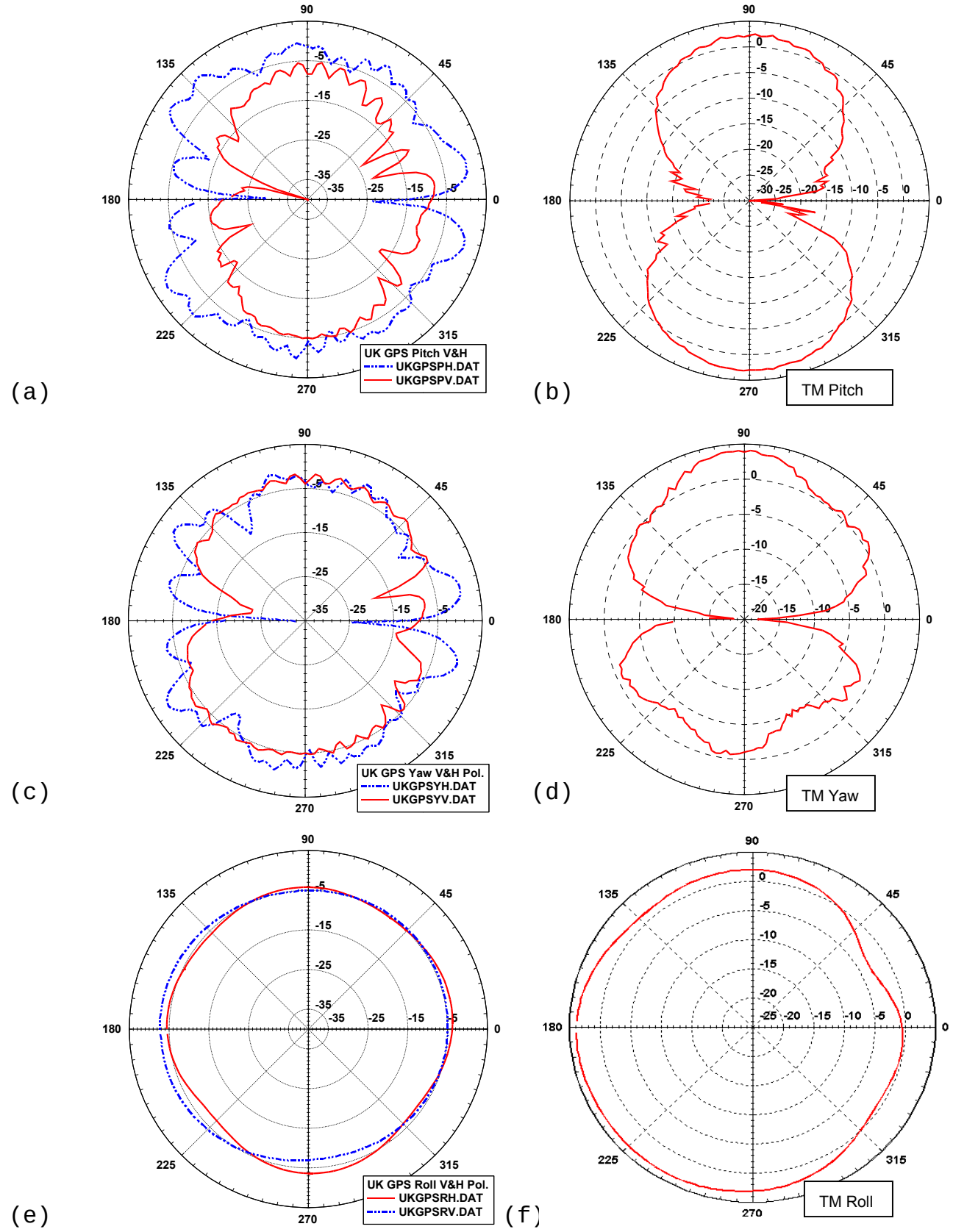

Figure 4. GPS and TM Antenna Radiation Patterns.

several additional antennas. Another example of a combination TM and GPS antenna with filtering is shown in Figure 5. A ceramic GPS antenna is used on top of two boards that provide the TM antenna and the bottom two boards are the filters for the GPS and TM antennas.

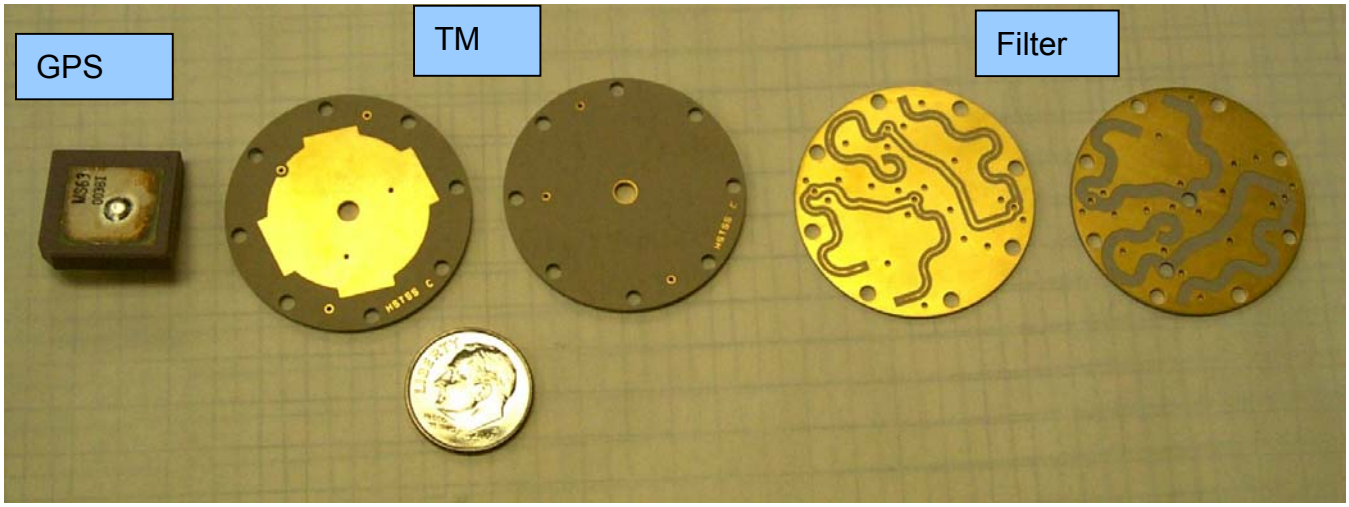

Figure 5. Photo of GPS and TM antenna and filter.

CONCLUSIONS

The latest status of the development of a GPS/TM antenna system that contains an integrated Limiter/Filter/Amplifier for various missile platforms has been discussed. The effort to integrate the voltage converter is currently under investigation and development.

REFERENCES

[1] Ryken, Marvin; Kujiraoka, Scott; and Davis, Rick; "Design of a GPS/Telemetry Antenna with Integrated Filter/Limiter/Amplifier for Small Diameter Projectiles," Proceedings of the International Telemeter Conference, Vol. 36, San Diego, CA, October 2000.

[2] RT/Duroid® is a registered trademark of Rogers' Corp., Chandler, Arizona.

[3] Ansoft Designer™ and HFSS™ are licensed software packages of Ansoft Corp., Pittsburgh, Pennsylvania.

[4] Eagleware is a licensed software packages of Eagleware Corporation, 635 Pinnacle Ct., Norcross, GA 30071.

[5] Orcad Layout is a licensed software packages of Cadence Design Systems, Inc.