Multi-Band Frequency Selective Surface (FSS) Antenna System: Packing more communications capability into less footprint

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Command: SPAWAR
Topic: N03-147, Multi-band Antenna for L, S, and X-band Data

PROBLEM STATEMENT

Meteorological/oceanographic (MetOc) satellite data terminals on two dozen Navy capital ships must start receiving X-band MetOc data when the National Polar-orbiting Operational Environmental Satellite System (NPOESS) system is launched beginning in ~2010. The constellation of three NPOESS satellites will transmit tactically important MetOc data in the X-band. However, existing Navy shipboard (SMQ-11) and shore-based (SMQ-11 and FMQ-17) MetOc terminals receive only L-band and S-band data. Further, these aging MetOc terminals are due for refurbishment or replacement.

WHO CAN BENEFIT?

All military services must add X-band capability to their meteorological plus certain other terminals for the NPOESS era that begins around 2010:

- Navy: 33 SMQ-11 and 11 FMQ-17 terminals.
- Marines: Meteorological Mobile Facility Next Generation systems.
- Army: Distributed Common Ground System-Army (DCGS-A) terminals. (DCGS-A consolidates meteorological and intelligence data reception)
- USAF: Transportable terminals.

Further, satcom-on-the-move (SOTM) and other multi-band satellite communication (satcom) transportable terminals can also benefit from this technology. Lightweight,

transportable, multi-band terminals can be built that can point at, and simultaneously communicate with, different communications satellites. Shipboard satcom radomes can be consolidated, with two or three different lightweight antennas housed in one radome.

BASELINE TECHNOLOGY

Heritage MetOc terminals throughout DOD — shipboard, land-based, and transportable — receive only heritage L- and S-band satellite data. A dual L- and S-band SMQ-11 shipboard terminal is shown at right. This is inadequate for the NPOESS era, where mission-critical and high-rate data from 11 different instruments will be transmitted in the X-band. To receive these data, a MetOc terminal must have an X-band antenna and receiver. NPOESS High Rate Data (HRD) contains all sensor data at maximum resolution and will be downlinked via X-band at 20 Mbps. Low Rate Data (LRD) contains a subset of NPOESS data and will be downlinked via L-band at 3.88 Mbps.

TECHNOLOGY DESCRIPTION

Syntonics' patented frequency selective surface (FSS) antenna system packs more communications capability into less footprint for SOTM, transportable, and shipboard satellite terminals. Multiple independent, lightweight antennas are packaged within a single radome. Each antenna operates in its designated frequency band while tracking different satellites.

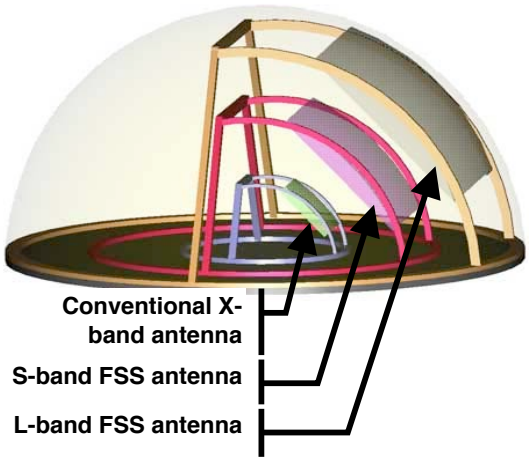
- This capability is especially useful for meteorological data, which is provided by both geosynchronous and polar-orbiting satellites. The FSS antenna system can simultaneously track different polar and geosynchronous satellites, continually receiving data from both. A shipboard system should cost less than $250,000.

- This capability also makes it possible to combine multiple satcom antennas within one radome. This is especially useful in shipboard and transportable systems, where reducing the footprint and weight of the antenna system is valuable. A transportable system should cost less than $25,000.

Syntonics is prototyping a tri-band antenna system with three independent antenna arrays, one each for L-, S- and X-band reception. The antenna pedestal design nests all three antennas concentrically within a single radome, permitting independent all-sky pointing for each antenna. The prototype antenna system will provide the same L- and S-band performance as the heritage SMQ-11/FMQ-17 systems while adding X-band capability.

The figure at right shows how each independently pointed antenna achieves its own all-sky view:

- The innermost X-band antenna can be any conventional design.
- The middle S-band FSS antenna panel is RF-transparent in the X-band. The X-band antenna can "look through" it.
- The outermost L-band FSS antenna panel is RF-transparent in the X-band and S-band. Both the X- and S-band antennas can "look through" it.



The antenna system also incorporates these design features:

- The FSS antenna panels are structural foam sandwiches. Antenna elements and FSS ground planes are printed with conductive ink onto Mylar film and bonded to create an exceptionally strong, stiff, lightweight, non-corrosive, and inexpensive structure. The antenna system will be significantly lighter than the SMQ-11 — perhaps half the weight — while packaging 50 percent more communications capacity into the same footprint.

- Sheltering the antenna system in a radome will achieve maintenance cost reductions compared to the SMQ-11, reducing Total Ownership Cost.

- The antenna system radome mounts on a three-degree-of-freedom (3-DOF) base to segregate motion compensation from antenna pointing. The 3-DOF base compensates for gross ship motion (i.e., pitch, roll, yaw). The antenna pointing mechanisms can now be much lighter and lower power.

Features, Advantages, and Benefits of Syntonics' Multi-Band FSS Antenna System

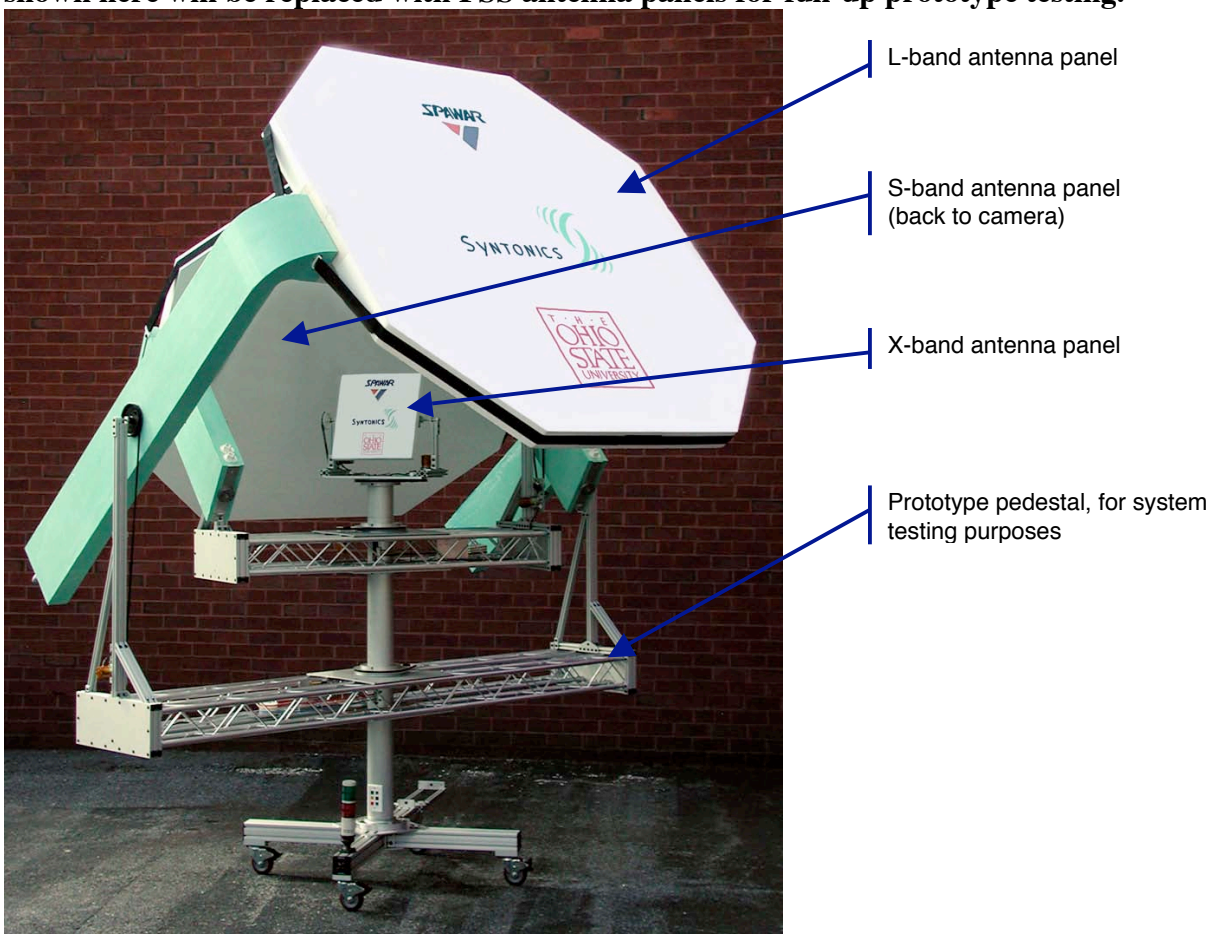
Feature	Advantages	Benefits to Navy
Three independent antennas, one per frequency band	Can simultaneously track up to three geosynchronous and polar-orbiting satellites	Enables continuous MetOc data reception from polar and geosynchronous satellites
One radome for three independent antennas	Maintains SMQ-11 footprint while increasing system capability	Can add X-band capability for NPOESS era with minimal impact to ships
FSS antennas are structural foam panels	Antennas are strong, stiff, lightweight, non-corrosive, and inexpensive	Low Total Cost of Ownership, lower topside weight
Radome mounts on 3-DOF ship motion compensation base	Antenna pointing mechanisms simplified	Reduces maintenance complexity

Feature	Advantages	Benefits to Navy
X-band antenna can be of any design	No development required since FSS panel not required for innermost X-band antenna	Low Total Cost of Ownership

CURRENT STATE OF DEVELOPMENT

Prototype FSS antenna panels are fabricated and a tri-band pedestal suitable for RF testing has been built. The FSS panels will be tested beginning in February 2006 for RF performance and then integrated into a tri-band pedestal. The integrated system will be tested in the ~March-April 2006 timeframe. Successful testing will demonstrate TRL 6. A CAD rendering of the prototype system is shown on the first page. The pedestal developed for Phase II testing is shown at below, integrated with antenna panel simulators for functional testing. All antenna performance testing will occur in the Compact Range of the ElectroScience Laboratory, The Ohio State University, Columbus, OH.

The pedestal developed for Phase II testing can be remotely commanded to point all antennas independently in azimuth and elevation. The antenna panel simulators shown here will be replaced with FSS antenna panels for full-up prototype testing.



TECHNOLOGY AVAILABILITY

Shipboard-qualified terminals using FSS antenna technology can be available in time for the NPOESS era. Syntonics is actively seeking a partner with strong credentials in satellite communications terminals plus shipboard antenna pedestal design to move this technology into the Fleet. We are also actively seeking funding to develop a lightweight, multi-band SOTM antenna system.

TRL	Required Tests and Demonstrations	Target Date	Required Funding
	Current SBIR Phase II contract:		
5	Design prototype FSS antenna panels and pedestal for testing	2005	(Already funded)
5	Test prototype FSS antenna panels	2006	(Already funded)
6	Integrate prototype FSS antenna panels onto pedestal and test	2006	(Already funded)
	Future Phase III contract(s):		
6	Develop and test next-generation FSS antenna panels plus prototype tri-band pedestal • Use ESL/OSU Compact Range to test antenna system • Subcontract with shipboard antenna pedestal expert to develop pedestal design	2007	~$2500K
7	Refine and test integrated antennas + pedestal system • Use ship motion simulator (e.g., at NRaD Warminster, PA) to test pedestal • Use NPOESS Test Bed at NASA/GSFC Direct Readout Project to test antenna system	2008	~$2500K
8	Develop and qualify pre-production FSS antenna system	2009	~$3000K
9	Demonstrate operational FSS antenna system onboard ship	2010	~$2000K

REFERENCES

These SPAWAR personnel are monitoring this project:

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The ElectroScience Laboratory of The Ohio State University (ESL/OSU) is conducting all FSS antenna performance measurements. ESL's Compact Range for measuring antennas and scatterers from 300 MHz to 100 GHz is world-renowned. FSS antenna system tests are being coordinated by Dr. Eric K. Walton, ESL/OSU, 614.292.5051, *Walton.1@osu.edu*. To date, two technical papers have been presented describing this technology and initial test results. There are available upon request.

1. E. Walton, E. Lee, D. Kohlgraf, R. Pavlovicz, G. Bruce, B. Montgomery, *Compact Shipboard Antenna System For Simultaneous Communication With Three Separate Satellites*, OCEAN 2005 Conference, October 2005, Washington, D.C.
2. E. Lee, *Design and Testing of a Feed Network For a Transparent Antenna Array*, AMTA meeting, November 2005, Providence, RI.

ABOUT THE COMPANY

Syntonics designs, develops, and manufactures specialty military RF communications equipment and accessories, notably RF-over-fiber products and innovative antennas. The company was founded in 1999 as the first "technology transfer spin-off" from the Applied Physics Laboratory of The Johns Hopkins University (JHU) and is owned by its employees and JHU. Syntonics' Quality Management System, registered under ISO9001-2000 since 2002, ensures quality products on time, every time.

ISO 9001:2000
FM 69168

Syntonics' FORAX RF-over-fiber system connects and opto-isolates multiple tactical radios to distant antennas using a single long, lightweight, secure fiber optic cable. Developed for USSOCOM, FORAX is installed in military command centers in the U.S. and deployed with U.S. and allied tactical military units.

Syntonics' Handheld Tactical Antennas are lightweight, rugged, low observables, and silent in use. They provide long-range communications for handheld and man-pack radios. Also developed for USSOCOM, current models meet VHF, UHF, broadband, and satcom applications.

A dual-mode antenna system for Unmanned Underwater Vehicles, in development by Syntonics for the Navy, supports both satcom and line-of-sight communications.

[No picture available]

The PICO Advanced Clock, prototyped by Syntonics for the Navy, provides precision GPS holdover timekeeping for several hours without using an atomic clock.