TRIAD RF SYSTEMS

TECH BRIEF

Keys to Successful Naval Defense MIMO/MANET Radio System Deployment

INTRODUCTION

Naval assets are designed and operated to perform a multitude of missions. The missions range from transporting and supporting air assets, conducting maritime patrol, transporting troops and supplies for land operations, and operating and coordinating unmanned assets. Missions require that maritime vessels coordinate and communicate with a large number of disparate assets. As such, naval vessels require numerous and varied communication methods.

Naval vessels operate in a dynamic environment that requires a wide array of communication links or off-ship bearers. An off-ship bearer is any method that transports information to or from a maritime asset. Since the early days of spark-gap Morse code transmitters that allowed for wireless communication over distance, maritime assets have sought additional communication methods for safety reasons and to allow them to expand their operations and missions. This never ending thirst for transferring more information over greater distances with greater numbers of end points has led to a dizzying hodgepodge of transceivers, amplifiers, and antenna equipment, all battling for height and optimal locations on the topside masts on modern naval vessels.

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Further compounding this already congested environment of high-powered emitters and potentially self-interfering equipment, is the ability of near-peer adversaries to use these emanations as a way of locating and targeting maritime vessels and to actively jam communication bearers, leading to the need to carry out operations with limited or no access to strategic communications due to anti-access/area-denial (A2/AD) threats.

At the same time, maritime operational requirements grow ever more complex. The introduction of unmanned systems is a powerful strategy to combat these adversaries and allow the world's navies to do more with less. For this reason, designers of naval vessels understand the need for autonomous, high-capacity bearers that can operate independently in A2/AD environments, adding and removing members automatically and seamlessly. This need has led to amazing advancements over the past years with Mobile Ad-Hoc Networking (MANET) radios.

A new spin on an old technology?

You may ask, why not modify or adapt one of the current off-ship bearers to perform this new function and answer the call for a high-capacity, autonomous, self-forming and self-healing network? This would be much simpler and less costly than introducing a new technology.

However, when you examine the existing off-ship bearers, you find that most fall short of the three main requirements:

- High-capacity data
- Autonomous operation (no single network master node)
- Self-forming and self-healing network

With all maritime communications bearers, there are a wide range of frequencies, waveforms, network technologies, and power levels. All of these come with both advantages and disadvantages.

HF radio technology is one of the earliest and most wide-ranging technologies on maritime vessels. HF radio can travel long distances (well beyond the visual line of sight), however, it requires a lot of power. It can also be unreliable in certain meteorological conditions and has limited bandwidth. Engineers are advancing this field using Automatic Link Establishment (ALE) and new protocols, such as High Frequency Internet Protocol (HFIP) to automate and standardize data transmission and reception, but these new approaches cannot fix the fundamental issues with the HF spectrum challenges.

VHF/UHF radio is another mainstay of maritime vessels for transmitting voice and data on and off the ship. Traditionally, these are line-of-sight tactical radio links, allowing for immediate, point-to-point transfer of voice and data. In recent years, technologies such as Subnet Relay (SNR) and protocols such as Variable Message Format (VMF) try to react to the modern day needs described above, but fall short on capacity. Some also require complicated configurations and controller nodes that do not lend themselves to truly autonomous network forming and healing.

SATCOM, or Satellite Communications, is a huge leap forward in technology and was quickly adopted by international navies around the world. SATCOM allows a ship to communicate dependably over long distance from practically anywhere a mission demands. It also provides an amazing leap forward in bandwidth capacity. However, with current demands for even more capacity, SATCOM still struggles to keep up with demand. Further, it introduces latency compared with a point-to-point link for assets within line of sight. In addition, SATCOM equipment can be extremely costly and complicated, sometimes requiring multiple large-dish radomes that require valuable deck space in already congested environments. With the increasing demand for more and more users, SATCOM technology has introduced technologies such as Demand Assigned, Multiple Access (DAMA), Integrated Waveform (IW), and most recently Mobile User, Objective Service (MUOS) which depend heavily on network controllers and require precise coordination of air-time shared between assets. Additionally, SATCOM has always been and will continue to be a major target for near-peer adversaries. There is no doubt that SATCOM is a major player in maritime off-ship bearers, however, it struggles to meet the three basics requirements listed above.

Tactical Data Links are the closest currently deployed technologies that align with our needs. There are numerous types of tactical data links and numerous implementations. So many in fact, that you may struggle to define them all and find their underlying similarities. Tactical data links are specifically designed for transferring high-capacity data. They typically work in a point-to-point, or point-to-multi-point configuration with a predetermined network topology and user list. There is no shortage of technologies, frequencies of operation, or manufacturers of these data links. In fact, there is an entire industry built on translating/correlating/coordinating technologies such as Link-11, Link-16, Link-22, to provide a common operational picture. Most tactical data links are point-to-point or depend on central controllers, remote users who follow a strict set of rules to access airtime and receive tactical data. In other words, not many of the tactical data link technologies present on maritime vessels can operate in an independent manner.

It would be extremely difficult to adapt one of these present technologies to meet the current needs and demands of modern day maritime requirements and unmanned systems. In addition, such an adaptation redirects these assets away from their traditional jobs as off-ship bearers.

A RADIO REVOLUTION

The introduction of software defined radios (SDRs) in the 1990s led to a radio revolution, for the first time decoupling waveforms from hardware and allowing a new agile approach to waveform generation and radio protocols. One major improvement was the introduction of adaptive networking protocols, which allowed for ad hoc radio networks. Ad hoc radio networks allow all radio users within range to communicate with one another. When coupled with mesh networking, broadly described as the ability for radio users to be added and removed on-the-fly and for any radio to retransmit received packets, the increase in capability is compounded.

In only the last five to ten years, new radios are staggeringly increasing network bandwidth and robustness, and depend less on centralized controllers. Some do not require any centralized management whatsoever.

You can tell how powerful these new radio technologies are just by seeing how quickly military forces adopt them around the world. Military users are typically the last to adopt new technologies, because they require dependability first and capability second. However, these new radio systems have quickly proven that the generational leap in capability does not come at the cost of dependability. Military organizations around the world are quickly pivoting to integrate these new systems into all types of platforms.

MIMO turns an industry on its head

Multiple-input and multiple-output technology (MIMO) uses multiple receive and transmit antennas to increase the capacity of a network. Using multiple antennas is not new to maritime communications and exists in the basic form of receive diversity. This method uses several antennas within the topside configuration that are physically separated. The receiver selects the best signal from one of the antennas. This minimizes fading and multi-path losses. However, receive diversity pales in comparison to modern day implementation of MIMO technology.

Advancements in computing and embedded systems have allowed for huge leaps in on-board processing within these very small radios. Advanced digital signal processing (DSP) techniques occur within the radios in real time to achieve amazing results. So amazing, in fact, that MIMO takes inherent disadvantages that have plagued radio communications, such as multi-paths caused by reflections, and turns them into advantages. By taking advantage of the diversity of these received radio waves and implementing DSP techniques within the radios, MIMO radio systems effectively increase the capacity of the system to receive data.

Similarly, on the transmission side, MIMO radios can use multiple streams of the same data signal to time encode error correction. In addition to this, some radios also implement a spatial multiplexing technique that allows multiple, separate streams of data to be transmitted at once, thereby increasing network capacity in yet another way.

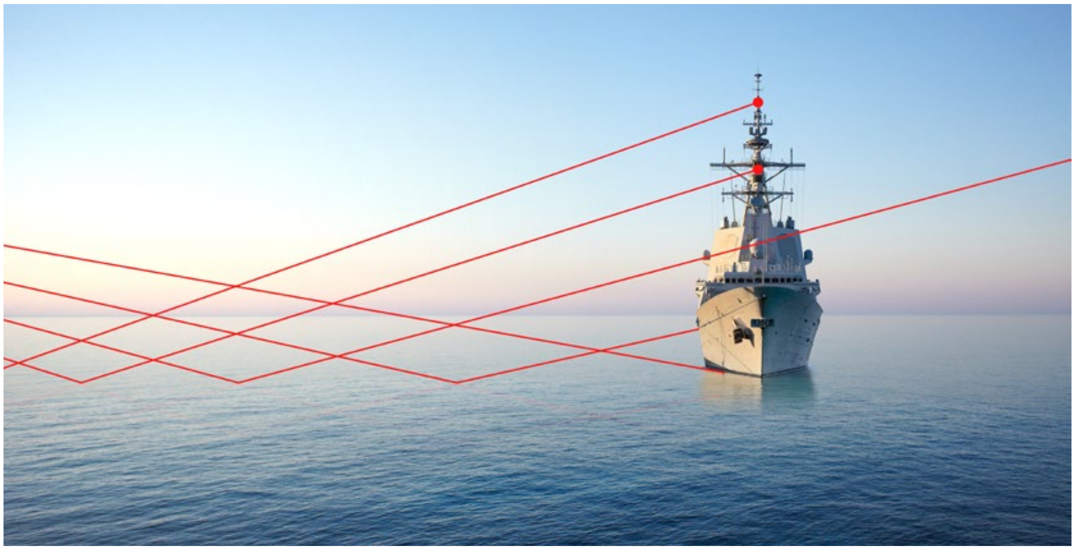

Figure 1

A simplified visual representation of RF wave reflection in a maritime environment.

MIMO/MANET: a match made in heaven

More recent advancements in these radio systems include spectrum monitoring, interference resiliency, and Low Probability of Intercept/Low Probability of Detect (LPI/LPD) waveform advancements. When coupled with the self-forming and self-healing advantages of the MANET implementation, these MIMO/MANET radio systems' ability to operate in A2/AD environments become that much stronger.

These radio systems, made by Silvus Technologies, Trellisware, and DTC to name a few, are distinctly suited for operation in a complex maritime environment. They can implement ship-to-ship, ship-to-shore, and ship-to-air links, allowing your mesh network to dynamically grow or shrink as operations dictate.

Traditionally, the complexity of designing a network like this, which can operate between such a diverse set of members would be a herculean task. It is nearly impossible to plan for every eventuality ahead of time. But today, these systems can be offered in high-power solutions that have the Size, Weight, and Power (SWaP) to accommodate these factors, as well as micro solutions that cater to unmanned systems where SWaP is at a premium. They provide unprecedented network capacity and the ability to adapt to changes within the network. In addition, the cost of these new systems is comparably low compared to legacy tactical data link solutions, which don't meet the current needs of the end users.

MARITIME CHALLENGES

Maritime communication design, installation and integration, and deployment are challenging, even when using proven legacy communication systems. There is a lot to consider in a maritime environment and on maritime assets. Just to name a few, there are:

- The effect that the water's surface has on signal polarization
- Water and air temperature changes that can cause atmospheric lensing
- Increased reflection resulting in destructive interference at distance
- Air density variations that can negatively affect RF propagation
- Weather conditions such as rain that can scatter an RF signal

Couple these with the fact that every maritime platform is typically moving through and with the sea, which leads to the additional effects of ship motion.

Maritime MANET design considerations

In reaction to these challenges, MIMO MANET radio systems have numerous configurations that can both combat and fall prey to these. You must approach maritime implementation from a knowledge-based view to implement your network for optimal performance. The following are some design considerations:

- Frequency selection – One of the biggest factors to consider with a Maritime MANET radio system is frequency. There are various choices available with corresponding advantages and disadvantages.
- Antenna specifications – There are a number of considerations when selecting an antenna.

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- Antenna location – This is always a struggle on ships because every communication system wants to be high atop the mast. Higher is almost always better and there is no exception here. In addition, MIMO systems require multiple antennas to increase the diversity of the transmitted and received signals. Other considerations are the location of the antennas and any near-field blocking that may occur.
- Antenna types – The types of antennas you choose greatly affect network performance and are highly dependent on the nature of your maritime operations. For instance, if you're flying a UAV mission from a ship, a high-gain, self-stabilized directional antenna is ideal. However, the properties of this type of antenna do not lend it to a mesh network implementation since you can point to only one remote user at a time. You may need to add an omnidirectional array to the configuration.
- Antenna polarization – You can use antenna polarization to increase diversity in transmitted and received signals. However, you have to design a system to be compatible with far end-user platforms such as other ships, land installations, or air assets. Typical options are vertical/horizontal polarization and left/right slant polarization.

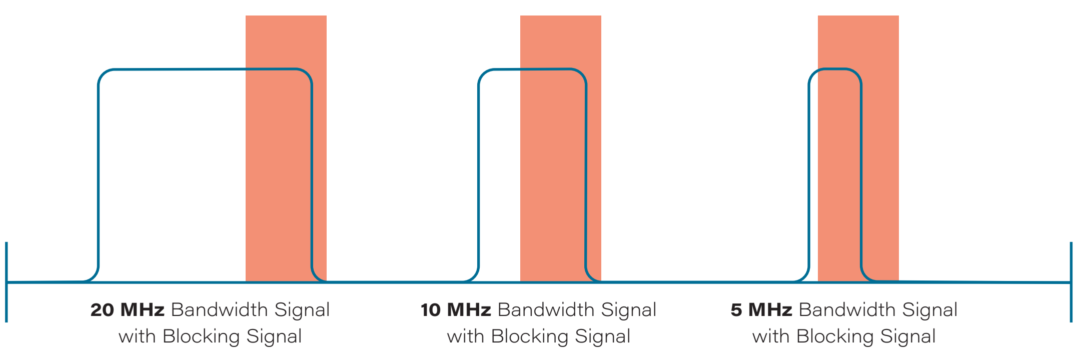
Radio-specific considerations

The following modern radio systems allow for a vast array of settings that can affect the system's performance:

- Bandwidth selection – Most modern MIMO/MANET radios allow for bandwidth as low as 1.25 MHz and as high as 20 or 40 MHz. Lower bandwidth settings are more sensitive to received signals, but more susceptible to intentional or unintentional interfering signals. In contrast, higher bandwidth settings allow for higher data rates and provide more robustness to interfering signals, but become less sensitive to received signals.

Figure 2

The effect an interfering signal would have on signals of various bandwidths.



- Modulation selection – All modern MIMO/MANET radios allow a user to select the modulation scheme for the radios. In addition, most recommend setting the radio to an adaptive setting, which will automatically select the modulation scheme for the user. However, there are complications to the modulation selection that you must consider.
- Error correction – In a maritime environment, you will undoubtedly encounter blockages due to external interference and destructive interference due to reflection. Error correction gives you a tool to mitigate these hazards, however you will introduce latency of the system to provide this additional correction overhead.
- Guard interval – As latency increases, you must also adjust the guard interval of the radios within the mesh to compensate for increased delays.
- High-power output – Regardless of network requirements, high power solutions are required in a maritime application. By boosting the output power of these radio systems, you can overcome a lot of the challenges that would simply not allow a lower power system to operate. There are solutions presently available that offer a maximum 5 Watt transmitted signal. In contrast, there are MIMO solutions available that allow for 4-channel operation at 50 Watts per channel. Amplifying these highly modulated signals is no simple task; you must be approach this task with care and experience. Drift of both radio and amplifier over frequency and temperature can produce vastly varying results, which you must account for.

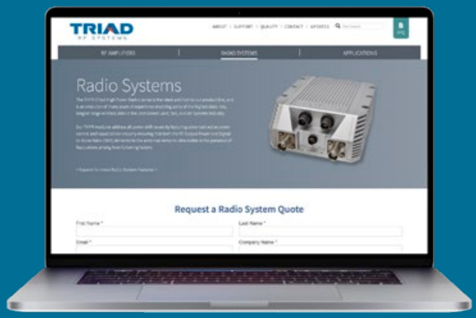
CONCLUSION

A continuous thirst for transferring more information over greater distances with greater numbers of end points has led to a dizzying hodgepodge of transceivers, amplifiers, and antenna equipment, all battling for height and optimal locations on the topside masts on modern naval vessels. As maritime users look to solve this challenge with next-generation high-capacity, distributed, dynamically forming/healing radio networks, industry is responding with highly capable, MIMO/MANET radio systems. But there are several keys to getting it right. You must deploy these systems with care and knowledge to ensure they can meet the complex requirements. And you must take into account many variables—from initial design to shipboard installation to deployment. Identifying the right technologies and partners early on therefore becomes chief among the keys to successful MIMO/MANET deployment.

NEXT STEPS

The Triad Advantage

Seamlessly achieve optimized ISR radio links with a Triad Amplified Radio System. Learn more at **www.triadrf.com/radio-systems**



About Triad RF

Triad RF is an AS-9100 certified aerospace manufacturer and offers full MIL-STD solutions. Our solutions are designed with the larger system operation in mind. This includes options for remote control and monitoring by maritime Communication Control and Monitoring Systems (CCMS.) We offer solutions in various physical sizes and configurations, including solutions intended to be exposed to the harshest of elements. We also offer varying power solutions to accommodate for our users SWaP limitations. This includes systems that can transmit up to 200 Watts for large ships all the way down to 10 Watts for UxVs

About the Author

Patrick Sherlock has bachelor's degrees in Electrical and Computer Engineering and a Master's degree in Engineering Management. Pat has spent over 20 years working on designing, integrating, and implementing naval communication systems within the United States and internationally, including Canada, Australia, New Zealand, Turkey, South Africa, South Korea, as well as many others. Pat has received numerous awards for his work including a Deepwater Award for Excellence from the United States Coast Guard for his "exemplary performance of duty while assigned to the Integrated Deepwater System (IDS) Program." Pat has most recently joined Triad RF Systems, Inc. as their Vice President of Business Development, focusing on MIMO/MANET radios and amplified radio systems.