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MIMO Systems for Military Communication/Applications.

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ABSTRACT
The Military is embracing the communication revolution, turning to a new generation of sophisticated systems to enable faster, richer, less costly, more flexible, reliable, compact, mobile, jam resistant, low probability of detection, re configurable and spectrally efficient communication. Many of these features can be added to a great extent in the existing systems, by utilising MIMO technology appropriately and judiciously. MIMO finds applications in wireless communication, NLOS communication, satellite communication, HF communication, Optical Fibre Communication. MIMO makes these technologies more suitable by introducing features mandatory for military communication such as Ant jamming capability, Low Probability of Intercept, low visibility of satellite earth Antennas by reducing their aperture area. MIMO can also provide redundancy by employing no extra resources, thereby increasing reliability. MIMO is highly effective to communicate with Unmanned Aerial Vehicles (1).
***Keywords*:**MIMO, Military, Satellite, HF, OFC, MBC , Channel Capacity, LPI , UAV, Aperture, Radar, Resolution , Survivability

I. Introduction

In the following paragraphs it is explained how the following features are introduced by using MIMO techniques.

i. Low Probability of Detection
ii. Anti-jamming capability
iii. Reduced visibility of equipment
iv. Communication on Unmanned vehicles moving with a speed of the order of 500-800 km/hr.
v. Redundancy of infrastructure to increase reliability

Fortunately all these attribute/requirements are met by MIMO system. Accordingly MIMO systems find their way in Military communication also. It has been demonstrated that ability to operate at speeds greater than 300 km/hr and a 17 dB reduction is the required T_x power for Covert, LPD communication, in addition to an interference/jammer mitigation technique based on MIMO Eigen beam-nulling has been demonstrated. It can be appreciated that for a UAV vehicle to communicate with ground has to face a hostile environment which includes Doppler shift due to moving plate form. The Doppler shift UAV moving at 300 km/h, operating at 4 GHz can be calculated as follows.

$$\text{Doppler shift}\left(f_D\right)=\frac{\nu}{C}f_0\ (1)$$

$$=\frac{300\times1000\times4\times10^9}{3\times10^8}=4\,\text{MHz}$$

The Doppler frequency drift is of the order of 4 MHz which has to be compensated to recover the information bearing data

To overcome such a high Doppler shift we adopt the following two approaches: We limit the size of a packet in between channel updates. The use of an advanced frequency-time pilot symbol insertion strategy to improve immunity of high Doppler communication.

1.2 Performance Vs Speed

The simulation results suggest for a 100 byte payload and a target PER (Packet error rate) of 10% a QPSK system suffers only a fraction of dB over two orders of magnitude variation in speed (from 5mph to 500 mph). Whereas 16 QAM is viable at speeds of up to 100 mph, and 64 QAM requires 42dB SNR at a speed of 100 mph. the RF impairments and practical synchronization algorithm introduces an approximate loss of 4dB, 5dB, and 12 dB at 10% PER and 100 mph, for QPSK, 16 QAM, 64 QAM, respectively. It is also clear that high constellation such as 64 QAM is desired at high speed, the receiver needs to be modified to combat the time varying fading which will cause the effective channel to be different between the start and end of the packet. The results at a target PER of 1% are significantly different, only QPSK can perform reasonable performance at speed up to 100 mph.

1.3 MIMO for LDP and AJ

The use of multi antenna techniques in covert or jam resistant communication is quite complementary to traditional spread spectrum techniques employing either direct sequence or frequency hopping. If covertness is needed (LDP), then MIMO techniques can help minimize the radiated energy via two or more distinct mechanisms. The first one is a direct consequence the benefits of spatial multiplexing, while the second is Eigen- beam forming and is superset of traditional beam forming techniques. In the case of AJ, multi antenna techniques can be used as Eigen-beam mulling subsystems or in the Eigen-spreading mode. The Eigen-spreading mode has the unique advantage of proving spatial averaging of jammer energy, analogous to frequency averaging in FHSS system.

1.4 MIMO for LPD

MIMO spatial multiplexing systems can provide LPD gain by simply trading off spatial (MIMO) gains for transmit power. Our first approach to gaining insight into the LPD properties of MIMO systems was to estimate the SNR required to achieve a capacity of 1 bit per second per Hertz. The study generated five hundred Rayleigh flat fading matrix channels and for each one the capacity equation given below can be evaluated for the required SNR The SNR when computed by setting the capacity (the left hand side of the equation) to 1 and solving for ρ.

$$C = E\left\{\log_2\left[\det\left(I_n + \frac{\rho}{n} H * H\right)\right]\right\} bits/s/Hz \quad (2)$$

In the above equation C is the capacity, $I_n$is the *nxn*identity matrix, H is the Rayleigh channel matrix, n is the number of transmit antennas, and ρis the average signal to noise ratio at each receive branch. The table below shows that at 5% outage, a gain of 22.1 dB is to be had if the number of receiver and transmit antennas is increased from 1 to 8. Another interpretation of the result is that if we want to guarantee that 1bps/Hz can be supported in 95% of all Rayliegh matrix channels encountered, then a lxl system needs an average SNR of 12.8dB at the receiver, whereas an 8x8 system requires an average received SNR of minus 9.3 dB..

Table 1.Required SNR to achieve a 95% capacity of 1 bps/Hz in Rayliegh channels.

MIMO Configuration	Required SNR to achieve 1 bps/Hz of Capacity at 95%
lxl	12.8 dB
2x2	1.2 dB
4x4	-4.9 dB
8x8	-9.3 dB

1.5 Enhancing Connectivity of Unmanned Vehicles through MIMO Communication (2)

The use of autonomous/unmanned vehicles for various civilian and military applications has become increasingly prevalent the absence of human pilots on board those unmanned systems, however, make it a challenging task to accomplish various intended missions. For example, these unmanned systems are often remotely piloted and thus having a reliable and robust communication link between the aerial systems and the ground control unit is imperative. Even for systems that are semi-autonomous, having a high throughput communication link is often essential to accomplishing any intended mission. Many remotely piloted aircrafts (RPAs) are used for surveillance applications and the need to stream surveillance data, including real time video data requires a highly reliable and high-throughput communication link from the RPAs to ground units (3).

Many legacy communication links (e.g., Link 16 with a data rate not more than (16kb/s) operate at a data rate that becomes highly inadequate for applications where video streaming from aerial systems to ground is needed. Merely scaling up the power/band width is both limited by resource and policy constraints as we1l as the fundamental theoretical limits dictated by the Shannon theory. A promising technology is the use of multiple antenna communication systems (4)-(5). The soca1led multiple-input multiple-output (MIMO) communication scales up data rate linearly as the number of antennas increase and thus provides great potential for improving the throughput of air to ground communication. This helps envisioned applications that may otherwise be infeasible.

MIMO communications, however, are traditionally designed for the so-called scattering environment (6) where independent channel variations between different transmit/receive antenna pairs are exploited. For airborne platforms, however, there has been a debate about the feasibility of MIMO communications because of the lack of scattering. However, for certain communication ranges, the large aperture that an aircraft affords makes MIMO an appealing choice of communication that can attain significantly higher throughput given a fixed power/bandwidth budget compared with single antenna systems even in the absence of any stutterers (7).Here we describes an ongoing research and development effort that uses MIMO communications to enable robust and high capacity connectivity between RPAs and ground terminals. While the large aperture may compensate for the lack of the scattering, two unique challenges still exist for airborne MIMO communications. The large aperture is only attained when antennas are placed strategically apart on a RPA. In the absence of scattering, i.e., when communications are limited by line-of-sight channels, the fact that some antenna elements on a RPA may be completely out of sight from its communicating party may render the channel matrix ill-conditioned. This is further complicated by the high mobility and manoeuvrability of the RPA which make it infeasible to have complete channel state information (CSI) at the transmitter. To address these challenges, it is proposed a variable rate MIMO communication scheme that combines the DBLAST architecture with per antenna spreading to harvest the maximum possible throughput gain allowed by the channel.

1.6 MIMO System with Displaced Ground Antennas for Board Band Military SATCOM

A powerful and reliable communications infrastructure plays a fundamental role in today's military foreign, operations for the provisioning of real-time information to all stake-holders (see figure 1.for illustration) Modern reconnaissance systems like unmanned aerial vehicle (UAVs), which are fundamental for low-risk(8) .

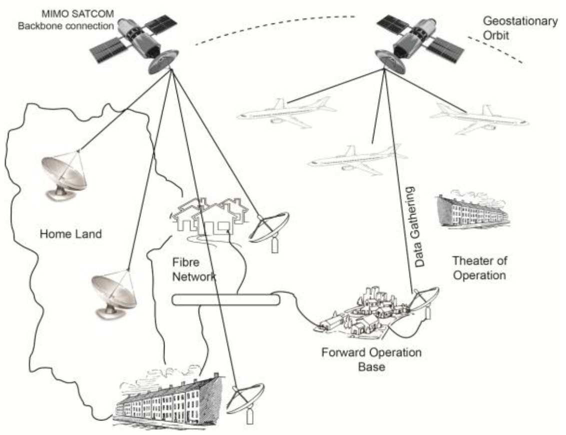


Figure 1.Military SATCOM scenarios.

Operations with respect to human lives produce an enormous amount of data. The immediate and permanent transmission of those broadband video and sensor data is essential to provide each combatant with a complete picture of the current situation. The entire raw data volume is usually gathered at a centralized location in usually the forward operation base where the sensor and video data is pre-evaluated, filtered and aggregated. The transmission to the home land is then performed via satellite. Geostationary satellite communication (SATCOM) systems for fixed-satellite services (FSS) are the backbone of military wide area transmission networks, enabling long-distance communication to almost any place or trouble spot in the world. Moreover, in the absence of any terrestrial communications infrastructure on site, geostationary (GEO) satellites provide highly available and wide range network coverage. Unfortunately, like the frequency spectrum, accessible orbit positions are a physically limited resource, which has led to exploding prices for SATCOM channels especially in regions that are in the global limelight. Additionally, the variety of military information and communication systems in today's multinational operations produces an enormous and further growing amount of data to be transmitted. Therefore, *bandwidth efficient transmission* has become a key performance indicator for customers and providers of satellite capacity and is, therefore, in the focus(28).

Due to the 'higher bandwidth efficiency compared to commonly used single-input single-output (SISO) systems, multiple-input multiple-output (MIMO) systems are appropriate to serve future data rate and bandwidth requirements in military SATCOM. The application of the multi-antenna technology leads to two basic system configurations (10): Firstly, the *single-satellite scenario* foresees multiple antennas on board one satellite. Secondly, the *multiple-satellite scenario* assumes one antenna element per satellite, i.e. two or multiple satellites act together as a single MIMO relay. Here we investigate the less complex single-satellite scenario with two antennas. The system involves also two ground antennas at the transmitter (Tx) and receiver (Rx) terminals, respectively, Hence, a 2x2 MIMO system is considered.

Moreover, we assume that the system provides *maximum' channel capacity.* To obtain a MIMO satellite channel with maximum multiplexing gain, distinct positions of the MIMO antenna elements are required. In this respect the inter-antenna distances at the satellite and the ground terminals are key parameters. In fact, in order to take full advantage of the MIMO capacity gain, large antenna separations either at the satellite or the ground terminals are necessary (10). As we investigate a single-satellite scenario, the inter antenna distance on board the satellite is naturally limited to a few meters by the satellite dimension. Thus, the inter antenna distances of the ground terminals have to be in the order of several tens of kilometres for maximum channel capacity.

Fortunately, the requirement of large antenna separations is well in line with military system architectures because the dislocation of strategically important objects is anyway fundamental. In order to prevent a loss of the complete infrastructure in case of an attack, generally a high degree of redundancy at geographically separated sites is considered. But also civilian SATCOM applications utilize separated ground terminals. Satellite ranging measurements for example demand large separations of the measurement antennas for high accuracy. Therefore, the proposed MIMO SATCOM systems for FSS just takes advantage of the existing standard infrastructure, adding the feature of increased bandwidth efficiency.

1.7 Reducing VAST Aperture for Satellite MIMO

For military communication while using satellite communication it is V. likely that the VSAT Antenna can be detected from the flying enemy Aircraft or by spying satellite itself. Once the VAST antenna is spotted it is likely to be destroyed. To reduce the chances the detection of the VAST antennas one of the potent approach is to reduce its diameter. So to reduce the probability of its detection and communication be achieved as required. To achieve this, MIMO technology is found to be use full to reduce the diameter / aperture of satellite Antenna (11).

Figure 2.shows a conventional duplex communication system using single satellite transponder with independent forward and return links. Typically, the hub- transmits informationto the remotes using a wideband carrier via time division multiple access (TDMA). The return link (from the remote very small aperture terminals - VSATs- to the hub)is typically single channel per carrier (SCPC, otherwise termed frequency division multiplexing). The SCPC and TDMA bands may not overlap (conventional system) or overlap (interference cancellation system, IC (13). A hub's antenna aperture (and gain) is usually much greater than the VSAT's. We demonstrate that VSAT antenna aperture can further be reduced by using satellite diversity(SD), space time codes (STC) or polarization diversity (PD) .

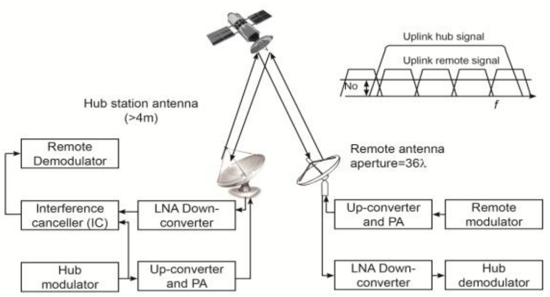


Figure 2. Single antenna SCPC/TDMA system with IC (Interference cancellation)

A VSAT's antenna gain, calculated as $4\pi A_e/\lambda$has half-power beam-width (in radians) of $\lambda / \sqrt{A_e}$, where $A_e$and λ, are effective antenna apertureand wavelength respectively (4). Parabolic reflector antennas with actual diameter of 36λ have a half-power beam-width slightly less than the typical satellite spacing of 3°. When an earth-station's antenna diameter is reduced by a factor of *k*, its gain is reduced by nearly k^2. For a one satellite system, the antenna points to a satellite, whereas for a dual satellite system, the antenna points, as in Figure 3, to the mid-point between two satellites.

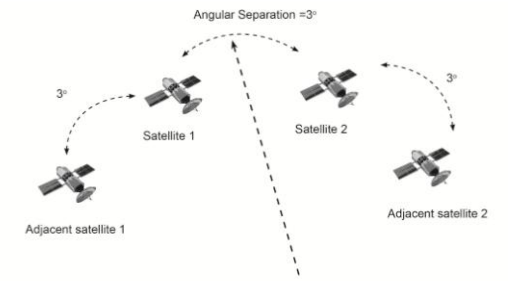


Figure 3.Pointing for q two-satellite receiver.

Let each path's power be scaled by a (pointing) loss factor corresponding to half the satellite spacing, denoted by $m_{0.5s}(k)$. For unchanged satellite transmit power for the land 2-satellite cases, the total received signal power will be identical when $k = \sqrt{2m_{0.5s}(k)}$ (iterative solution is necessary as the RHS is a function of *k*, but, practically, *k* is just $>2^{-0.5}$). Adjacent satellite interference (AS1- worst for co-polarized adjacent transponders) is a pointing factor of $m_s$and $m_{1.5s}(k)$ for the 1- and 2-satellite cases respectively. Main-lobe roll-off for antennas of interest are even $convex - \cap$, usually nearly $\cos^n\theta$ (pp. 36 of (20)), θbeing angular offset, or $[1-\theta^2/2]^n$for small θ, and *n* is πdivided by the first null beam-width; *k* is the solution of:

$$k = \sqrt{2(1-0.125s^2)^{kn}} \quad (3)$$

The ASI ratio, ρ, of the single satellite system to the 2-satellite system (with aperture reduced by k^2) is:

$$\rho \approx \frac{1-0.5s^2}{(1-0.125s^2)^{kn}} \quad (4)$$

ρis greater than 1 when:

$$k \le \frac{\log(1-0.5s^2)}{\log(1-0.125s^2)^{kn}} \quad (5)$$

For $s=3°$, ρ>1 when k>0.4441. A dual-satellite VSAT with the same uplink gain as a single-satellite VSAT has $1>k>2^{-0.5}$ with reduced ASI that depends only on *k* (and not modulation). In contrast, spread-spectrum methods (DSS) reduce ASI power spectral density (PSD) according to the bandwidth expansion factor.

Alternatively, a reduced-aperture VSAT's (e.g. maritime or man-pack VSAT) transmit power can be increased by a factor, *r*(<ρ),less a small performance loss (shown in following and subsequent sections), yet maintaining lower ASI. Any gain-ASI combination in between may be chosen, possibly allowing bandwidth-efficient (high-order) modulation to be used in the VSAT uplink (14).

Benefits of reducing aperture (using SD and STC or PD) are:

• Lower susceptibility to pointing errors and smaller antenna aperture reduce demands on:

• SATCOM-on-the-move sensor resolution and servo motor power (in adverse winds)

• Man-pack weight and terminal alignment time

• Smaller ASI allows increased terminal transmit power, allowing higher order modulations to be used

• Reduced antenna cost (for a phased-array by as much as a 4 factor for a 2-satellite system case)

Leasing two transponders, each at the same downlink power as just one, is offset by economy of larger scale production of smaller VSATs, or where small size has high intrinsic value (i.e., transportability and weight as in, man-packs).

The following section describes a scheme to reduce VSAT antenna aperture for a point-to-point system (the forward and return channels have the same differential delay and Doppler) using 2 satellites. In this case, the differential delay and Doppler are estimated via the return channel's diversity combiner (DC, which weights and sums the inputs of the IC's subtraction) (7). A rate 1 2xl STC encoding is applied after one channel is delayed and frequency shifted at the hub transmitter (differential delay and Doppler being estimated by the hub's receiver) so that the received signals are time- and frequency- aligned at the VSAT. Thus, challenging frequency offset and delay acquisition in STC receivers, is circumvented. The STC output is transmitted to the satellites via two large aperture hub antennas (Figure 4) and received by a smaller VSAT antenna pointed as in Figure 5.

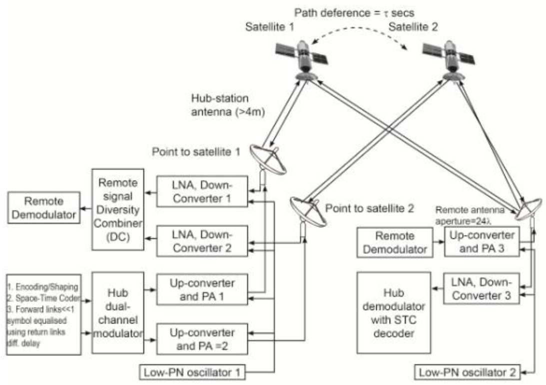


Figure 4. Point-to-point satellite link using 2x1 STC

Reducing remote antenna aperture for a point-to-multipoint system using 2 satellites, each transmitter configured for one (but not both) polarization at a time, is described in the subsequent section. Polarization diversity (PD) allows two channels' to be received from a single reduced aperture antenna. When the two diversity channels are repeated for transmission via two satellites. (Figure 4.), differential delay and Doppler are estimated via IC at the remote station, is applied at the DC receiver. When weather causes poor polarization isolation, the receiver uses two more ICs. This DC method, which acquires frequency and delay, does not require symbol timing recovery; i.e., a post-DC off-the-shelf demodulator may be used. The subsequent section's method also extends to multiple (>2) satellites (alternate satellites with same downlink polarizations) to obtain increased system gain and reduced ASI, VSAT power and aperture (but multiplying transponder lease costs).

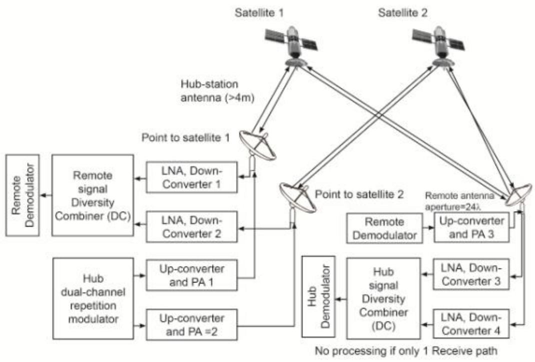


Figure 5. SD for point-to-multipoint topologies

II. Mimo In Hf Data Links

High frequency (HF) radians (3-30 MHz range) provide tactical communications with the ability to communicate over long distances and around large obstacles without supporting infrastructure of any type (satellite links, wired links, Towers etc.). The limitation with HF Band commutation is that the spectrum is V. limited and link quality in poor and varies a lot, form day to night, form summer season to winter season to rainy season and so on (15).

The HF Communication has the following main limitations which if overcome by using some innovative technology, it will be extremely useful for military application.

a) HF Communication quality varies as the ionosphere characteristics vary diurnally, seasonally, and yearly. The communication during sunrise and sunset is always subjected to great fluctuations in levels, due to changes in ionosphere.

b) A reliable HF Communication depends on the correct choice of frequencies and proper choice of Antenna. A minimum of three frequencies and proper antennas are required for satisfactory communication. A minimum of three frequencies are required for round the clock operation. We can depend on the ionospheric information provided by the committee of council of Scientific and Industrial Research, as published by National physical Laboratory New Delhi the working frequencies for the link can be computed.

c) The reliability of an HF Communication depends on the working frequency and the takeoff angle of beam.
d) The optimum working frequency in normally 85% of the maximum usable frequency.

Further HF data rates are currently too low to support reliable video or other date-intensive communication because of low Bandwidth allocations and challenging propagation conditions. Recent efforts have resulted in new waveform designed for wider bandwidths and higher data raters, the highest rates are only achievable in the most favorable conditions. These conditions will not be consistently observed due to the variability of the HF channel. Further, extending HF rates through bandwidth expansion is increasing difficult given the scarcity of acquirable HF spectrum and the challenges of changing international spectrum policy.

One approach to significantly increase data rates without expanding the spectral footprint is to utilize antennas, RF chains, and smart signal processing to communicate multiple streams of data in parallel. This techniques, known as Multiple-input Multiple-output (MIMO), has been successfully deployed in commercial wireless networks to provide multiplicative gains in data rates, robustness to interference, increased data link reliability, and reduced transmit power.

It has been demonstrated that the MIMO is feasible in a small-array configuration for near-vertical incidence sky wave (NVIS) links. NVIS communication also removes the limitation of HF communication not in a position to effectively communication for the short range of 50 Kms to 250 Kms and normally, the planning of fixed- to fixed services is not done for such distances. Whereas NVIS removes this limitation of HF communication and gets additional technology rich fetuses form MIMO usage.

It has been demonstrated that 2.27 times large data rates, 9 times less transmit power, and greater than 3 times fewer rink failure in 2x2 MIMO HF NVIS channels with cross polarization antennas by exploring both diversity and spatial multiplexing. It also provided critical channel metrics, including spatial correlation matrices, to enable base-band designs to benchmark performance and design MIMO HF protocols.

2.1MIMO Wave Form Design For Military Applications for HF

We assume MIL-STD-188-110-C-Appendix-D as the base line HF base line digital HF waveform operations on a single carrier with variable constellation configuration (including BPSK, QPSK, 8-PSK, 16-QAM, 32-QAM 64-QAM, 256 QAM, and a 32-length 8-PSK Walch sequence) The constellation symbols are transmitted at a variable rate between 2.4 kbp19.2 Kbps.(always an integer multiple of 2.4 Kbps) and filleted with a root raised Cosine fitter with a 35% excess bandwidth factor. This leads to spectrum occupation between 3-24 KHZ. Forward error correction is accomplished through binary convolution coding with two generators (with either 7 or 9 constraint length) producing a base rate ½ code. Puncturing enables rates of 2/3, ¾, 5/6, 8/9, 9/10, & 9/16. Cascaded repetition coding enables rates of 1/3, ¼, 1/6, 1/8, 1/12, 1/16, 2/5 & 2/7. The modulation & coding together provide data rates from 75 bps (in 3KHz spectrum with 32- symbol 80 PSK Walch sequence) to 120 Kbps (in 24 HZ spectrum with 256-QAM & rate 5/6 coding).

The properties of the proposed MIMO wideband HF wave form, which shows a balance between backward compatibility with legacy base line waveform implementation and new features that exploit MIMO to improve performance at all SNR. The most noticeable new feature is the ability to provide spatial multiplexing through the inclusion of two simultaneous data symbol streams. A convention of commercial standards is followed here, when spatial multiplexing is enabled, each stream selects the same constellation and the same coding rate(16),(17).

The proposed wave form also support diversity mode of transmission. Diversity made will be available through delay diversity made and space-time-block coding (format similar to Alamouti.) Delay diversity delays the output of the second transmit antenna by a fixed duration. At the receiver this essentially looks like multipath, converting spatial channel paths into temporal channel paths, which can already be captured in legacy systems. For non-legacy operation, space- time block coding is preferred. Space time block coding intelligently address redundancy across transmit antennas in a way such that the receiver can capture full channel diversity without knowledge of the cannel at the transmitter. Digital beam forming and closed-loop precoding diversity algorithm has been avoided since the variability of the HF NVIS, channel suggests that current work functionally operates on too large of a time scale to make precoding (beam forming) reliable. This may be revisited with justification of channel stability.

It has been seen that MIMO offers HF Links increased spectral efficiency, reduced transmit power, interference/ jamming robustness and extended reliability. Which are vital requirements for any militancy communication links (13).

2.2 HF Communication applying polarization diversity Multiple- Input Multiple- Output (MIMO) Can also be used as Military HF Communication.

Beyond line of sight (BLOS) Communications are predominately accomplished by satellite owing to V. high data rate offered by satellite system, due to the fact that spectrum available for satellite is of the order of few hundreds of MHz In spite of the fact that satellite communication is V. Capable, but it is also expensive and can be vulnerable to degradation and disruption. In order to maintain connectivity in challenging or denied environments, investigating the usefulness of HF Communication by increasing its capacity, robustness, and reliability is worth.

HF communication has generally been constrained by limited to narrow bandwidths. Traditional HF challenges also include channel fading and the need for large Antennas. There has been a number of efforts focused on increasing HF link capacity that include large BW, high constellation QAM signals (12-24 KHz), OFDM signaling with up to 256-QAM and advanced error coding, multicarrier 1x2 MIMO with time, frequency and polarization diversity and OFDM signaling & 2x2 HF MIMO with polarization diversity.

This has achieved spectral efficiency ranging from 1 to 4 b/s/Hz under favorable conditions and high bower. A new waveform has been developed for 2-antenna MIMO through the use of spatial multiplexing. Link Simulations on a 48-KHz Channel that use channel measurements form an NVIS Collection campaign show a doubling of data rate and improvement in bit prorate (BER) by up to 15 dB in comparison to single antenna. It has been demonstrated a wideband HF one way communication using a short hop (< 75 km) sky wave link. The new techniques and technology to wideband HF (WBHF) communication (up to 96 KHz). The development of WBHF waveforms that are not contained to the MIL-STD-188/110-C Appendix D family of wideband waveform standards. The polarization diversity MIMO technique coupled with advanced waveform coding for interference rejections. We leverage improved understanding and adaptation of HF channel phenomenology to emphasize low power operations with increased Bandwidths, Capacity, and reliability.

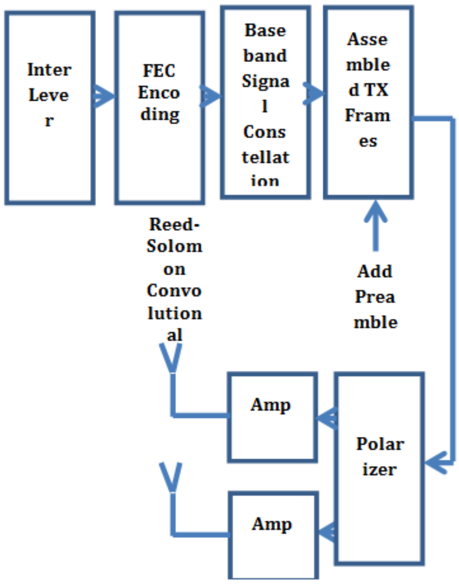
2.3 HF Communication Transmitter Proposed diagram

High level block Diagram & Transmission of higher data rate, polarization diversity HF Communication Transmission waveform.

The goal of our HF Communication design is to communicate reliably with acceptable bit error rate of the order of 10 in one million bits, or so, with spectral efficacy as high as of 1 to 4 bits/ S/ Hz. To achieve this polarization diversity can be exploited, so that data stream is split in to two parallel data streams of half the bit rate of original stream and each stream transmitted on two independent antennas after required FEC and other baseband processing. These modes of transmission an called X-and O-propagation modes of the ionospheres uncorrelated waveforms that carry independent information.

This approach approximately provides a throughput of 2 times, using the same band width, of curse at the cost of hard complexity and processing power of the processor used. The also improves robustness to multipath and channel fading.

In order that MIMO spatial multiplexing can be used it is necessary to add coding to the different channels so that the receiver can detect the correct data.



In fig 6, we drew a high level Block diagram of high data rate, polarization diversity HF Communication Transmissions/ waveform. Here the two independent data streams after processing at Baseband level, modulation are transmitted parallely on two separate polarized channels. At baseband level the data stream is FEC coded using Reed- Solomon and Convolutional forward error correction (EEC) to improve the immunity against noise, thereby improving BER performance in presence of both burst like and multipath fading that typically occurs at HF Communication media.

The coded data streams are then mapped to baseband signal constellation for low data rate (OFDM), medium data rate (BPSK), or high data rate (QAM) communications. The resulting data packets are assembled in to frames and orthogonal preamble waveforms are added to the beginning of each frame to distinguish the two polarization channel. The two baseband signal frames are then up converted in to a dual channel and simultaneously transmitted using orthogonal circler polarization, the left circular for channel one and right circular for channel two.

2.4 Fig below 6shows the block diagram of the signal processing employed in the receiver.

The baseband processing begins by reliably detecting the preamble or synch waveforms for each channel. This is accomplished using two dimensional complex ambiguity function (CAF) processing to estimate the delay, Doppler, and phase to the channels as a function of time. This process is carried out for every received data frame so that the current channel conditions can be estimated and tracked over time. The synch detections provide for accurate data packet alignment and phase compensation form which an N-point FFT follows to demodulate the received signal constellation. Note that the OFDM single tones are cleanly apparent in this example, the tone positions and/ or phases define the data symbols that were transmitted. A technique has also been developed for detecting and nulling strong narrowband interferences. This nulling process is followed by spectrum spreading which produces a clean signal constellation for subsequent processing. The next step involves FEC decoding which attempts to correct for any bit error that may have occurred during received single demodulation and bit recovery process. In the end the bit de-interlever, re-arranges the bits in the original form and data is ready to be used.

2.5 HF MIMO:-

Ionosphere multipath propagation and polarization diversity are explained to achieve an increased data Transfer speed and a decrease of necessary signal-to-noise ratio though HF Multiple input Multiple out but (MIMO) technology. The benefits of MIMO are discussed in (18) with simulation of MIMO on HF propagation paths and measurements at 12.5 MHz using narrow spaced Antennas. MIMO measurements over an 1800 km path between the Canary island and Spain (110) show that the MIMO gain that the can be achieved. High correlation factors ware measured however, even with large Antenna spacing, HF MIMO experiments in the United kingdom using near vertical incidence Sky wave propagation (NVIS) on 5.2 MHz are described in (19). Several antennas Configurations are compared by measurement and the mean correlation coefficient between 0.5-0.73 are established. Cross dipoles are found to show less correlation than vertical Antennas. The importance of the ordinary and extraordinary wave mode for HF MIMO is explained but no experiments are performed with circularly polarized Antennas. (20) contains a feasibility study of an HF MIMO system and investigates also the role of the ordinary and the extraordinary wave, assuming matched polarization. However, the study contains is based on simulations & is not validated result.

III. Mimo Communicatin Over Multi Mode Optical Fiber For Defence Applicatiaons.

Multimode fiber (MMF) links are widely implemented in current high speed local area networks. They can provide the necessary bandwidth for single mode fiber (SMF) solution, mainly due to the ease of optical alignment and packaging. In practical terms, the larger core size amplifies connections and also allows the use of lower- cost electronics as light-emitting diodes (LEDs) which operate at the 850 nm and 1300 nm wavelength. MMF can support DWDM or CWDM which makes links less vulnerable to vibration and temperature fluctuations as the source causing wavelength shifts. New generations of lases- matched MMF has been developed for high date rates over longer reaches OM4, for example will support the following (21)

400 meters at 2Gbps
200 meters at 8Gbps
130 meters at 16Gbps.

The data rate capability of MMF is augmented by using MIMO techniques. The required transmitter/receiver diversity for MIMO operation is realized by each transmitter launching light in to MMF which is slightly different modal power distribution, and furthermore, each receiver gats power form all the transmitters via a different distribution of modes too, as described schematically, in figure below(112):

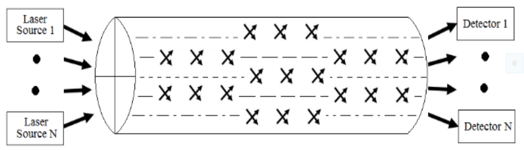


Fig 7. Multimode fibre with MIMO input/output and intermodal coupling

The key feature of optical MIMO is that it makes use of the modal dispersion MMF, rather than avoids it. In Stuart's approach, RF sub carrier (app.1 GHz) with PSK data formant was used for transmission modulation, followed by optical intensity detection and RF Coherent modulation. The use of RF subcarrier in intensity modulation and detection requires a V. long MMF, and places a minimum of subcarrier frequency in order to ensure enough model diversity, which is requirement for MIMO operation. In contrast, if coherent optical transmission is used the required length is reduced by the ratio of the RF subcarrier frequency to the optical carrier frequency. This eliminates the requirement, marking MMF channels more amenable for MIMO operation. Accordingly COMIMO has great potential in unblocking the inherent capacity of MMF and the coherent implementation is essential to ensure the necessary diversity for physically large fiber length. It also provides security benefit to the physical layer of link (22).

To sum up the bandwidth limitation of MMF as compared to SMF can be overcome by using MIMO techniques; The MMF finds special applications in military as follows:

1. Ease of optical alignment, when new connectors are to be made in the field, it is less sensitive to misalignment.
2. Low cost LEDs can be used as a light source which operates at wavelengths of 850 and 1300 nm; as the diameter /aperture of MMF is much more compared to SMF.
3. Since MMF can support DWDM (Dense Wave Division Multiplexing). DWDM which makes links vulnerable to vibrations and temperature fluctuations which is a specific requirement of military applications of fiber.
4. MMF provides security benefits to the physical layer of link.

IV. Military Use Of Meteor Bust Communications Using MIMO Techniques.

Meteor bust communication faded interest with the increasing use of satellite communication, which started in let 1960s. In the late 1970s it became clear that the satellite were not universally useful an original thought, notably at high altitude or where signal security was an issue. For these reasons,
The U.S. Air Force installed the Alaska air command MBC System in 1970s.

MBC communication capacity is small and with a bad Real-time performance. We want to analyse the results by using MIMO techniques. As we know MIMO uses multipath effects as a favourable factor, to resist the influence of meteor Bust communication channel decline and improve the communication quality and improve the system performance. The Space-time coding technology is used to realize multi-antenna technology performance. As a strategic communication system, MBC system can work steadily over long distance under sever conditions such as nuclear explosion, earthquake etc. In military applications it is developed for the minimum essential emergency communication network. In addition is it can be useful in a number of civilian applications essentially remote sensing where it can provide inexpensive communication techniques for hydrometeological date collection, polar exploration. Natural disaster warning etc. (23).

Diagram meter Brest Communication

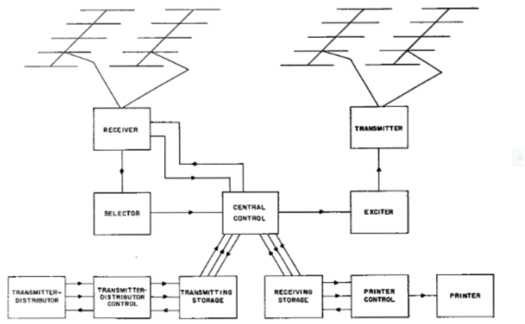


Fig 8. 2*2 MIMO Meteor Burst Communication Diagram (Source: Experimental Equipment for Communication Utilizing Meteor Bursts, by Robert J. Carpenter &Gerard R. Ochs.NationalBureo of Standards, Washington 25 D C)

5. MIMO Radar systems for military communication

It is a system of multi Antennas. Each waveforms antenna can receive these signals. Due to the different waveforms, the echo signals can be re-assigned to the single transmitter. From an antenna field of N transmitter and a field of K receivers mathematically results in a virtual field of K.N. elements within enlarged in a virtual aperture. MIMO radar system can be used to improve the spatial resolution, and they provide a substantially improved immunity to interference. By improving the S/N ratio, the probability of detection of the targets is also increased.

The MIMO radar systems can be closeted in to two categories

1. MIMO radar with collocated antennas (so called ‘Monostatic’ MIMO). The target is a point target as in traditional radar systems.

MIMO radar with widely separated antennas (so called ‘distributed’ or ‘Bi-static’ MIMO).

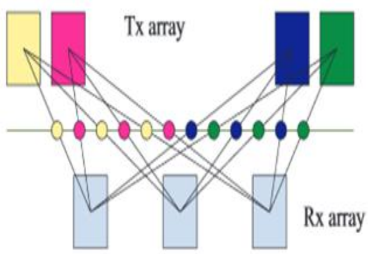


Fig.9. Generation of the virtual array for an ARTINO-configuration (the array axes of the Tx and Rx arrays may be parallel displaced leading to the same virtual array)

(Source: System Architecture & algorithms for Radar Imaging By: Joachim H.G. Eder. FGAN-FHR, NeuenehrerStr 20, D-53343, Wachberg, Germany.)

‘Monostatic’ MIMO: - In the collocated radar case the transmitting antennas are close enough such that the radar cross section {Rcs} observed by the transmitting antenna elements are identical. This system in similar to a thinned array of phased array antenna in which each radiator has its own transceiver module and its own A/D converter. However in a phased array antenna, each radiator only transmits (passively time-shifted) a copy to a transmission signal, which has been generated in a central waveform generator. In a MIMO reader system each radiator has its own arbitrary waveform generator and subsequently each radiator uses an individual waveform. This individual waveform is also the basis for an assignment of the echo signal to their source. It can be seen that MIMO and phased array, the passed array antenna is often described SIMO (Single input Multioutput).

Bi- Static MIMO: - In this arrangement of the antennas, the radar processing is much more complex. In contrast to “MONO Static” MIMO, each radar antenna looks at the target from a different angle. Therefore the target provides a different radar cross section of each radar Antenna. This requires much more complex target models for radar data processing. Like MIMO Communications, MIMO Radar offers a new paradigm for signal processing research. MIMO radar processes significant potentials for fading mitigation, resolution enhancement, and interference & jamming suppression.

Fully exploiting these potentials can result in significant improved target detection, parameter estimation, target tracking and recognition performance. The MIMO Radar Technology has rapidly drawn considerable attention from many researchers. Several advantages of MIMO Radar have been discovered by different researchers such as increased diversity of the target in formation, excellent interference rejection capability improved parameter identifiability, and enhanced flexibility for transmit beam pattern design. The degree of freedom introduced by MIMO Radar improves the performance of the radar systems in many different aspects. However it also generates some issues. It increases the number of dimensions of the received signal. Consequently, this increased the complexity of the receiver.

V. Applications Of MIMO –DSSS Based System

Spread Spectrum originated as a mean of secure communication in the military providing of single in the frequency domain to give a low peak power. To observers spread single looks similar to white noise, and hence has a low probability of intercept. Recently IEEE 802.11 task Gp. was organised with the goal to increasing the application throughput to as least 100 Mbps by making modification in PHY and MAC layer. This major variety in the PHY layer is the use of MIMO with orthogonal frequency division multiplexing (OFDM) system to support several parallel streams which is likewise known as multicarrier based techniques. It can mitigate ISI by addition of cyclic prefix as one of the option in OFDM. It can also Improve capacity in the wireless system with spectral efficiency in the wireless system with spectacle efficiency (bps/Hz) and assess specimen complicity in wireless broad band systems.

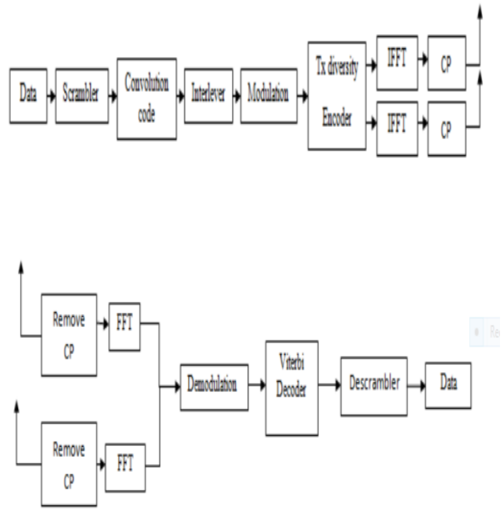


Fig. 10. System model of MIMO-OFDM-DSSS System

We can use MIMO technique for sustaining high data rate transmission. Digital communication using MIMO Processing comes forth as a break thought for revolutionary wireless systems. It solves two of the hardest problems facing the wireless technology today. Speed andrange. MIMO systems Promise to increase date rates. Reliability and performance with acceptable BER without increasing the transmit power and without consuming the extra radio spectrum.But MIMO cannot achieve zero ISI and hence easily be overlaid on a OFDM based system. The MIMO signalling treats each sub-carrier in OFDM as an independent narrowband channel. It can be viewed as an N parallel systems operating with flat fading channel Co-efficient. But MIMO suffers from Co-channel interference problems. It is the interference between uses in different cells using same frequency (Known as frequency Reuse),
results in CCI. Solation to that is to apply DSSS technique based on spread spectrum technology. The main advantage of Appling DSSS is that it reduce power signal that may mitigate CCI problem in MIMO-OFDM based system.

VI. Conclusion

It has been seen that the basic advantages of MIMO systems are blessed with the advantages of spatial multiplexing gain which increases the channel capacity by delivering more number of bits compared to SISO systems. Similarly it provides diversity gain which can provide rugged, reliable and increases the availability. MIMO also provides array gain which increases SNR of a system which can be translated into deducesBER,thereby improving the signal quality. MIMO by way of beam forming provides reduces inter system interference. All these advantages are required by military communication/systems. MIMO is specifically useful for military wireless communication, satellite communication, HF communication, OFC (Optical Fibre Communication), Radar systems provide improved resolution when MIMO is used. It is useful in many other military communication features of LPI,LPD,UAVs,to provide low visibility of satellite antennas by reducing their aperture etc.

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