Modern U.S. Navy shipboard high frequency (HF) communication requires the simultaneous transmission and reception of radio frequency (rf) energy. The associated antenna systems are necessarily located in close proximity on the ship platform. Current shipboard HF communications terminals have evolved as narrow band systems in meeting operational needs and mitigating local electromagnetic interference (EMI) problems. These systems employ elaborate rf filters in both transmitting and receiving antenna multicouplers. Future Navy operational requirements envision the need for simultaneous two-way communication having jam resistant (JR) and intercept resistant (IR) characteristics. The JR and IR modems under consideration and development utilize spread spectrum and frequency hopping techniques over wide HF bands, thereby precluding the use of narrow band rf filters as a solution to the local EMI problem. Other methods must, therefore, be pursued to reduce EMI in the receiving systems to acceptable levels. One method that appears to have potential for this purpose is the application of an electrically small antenna for the shipboard receiving system. The electrically small antenna provides a means of reducing the coupling between collocated transmitting and receiving antennas without necessarily sacrificing receiving system sensitivity.

The electrically small antenna, being 1/8 wavelength or less in its largest dimension, would have dimensions not greater than 1.25 meters in the 2 to 30 MHz band. A typical whip for current narrow band receiving systems is 10.67 meters in height. Figure 1 is a comparison of EMI voltage appearing across 50 Ω receiver terminations at the feed points of an electrically small antenna design [1] and a conventional 10.67 meter whip. The source of the EMI voltage is a 10.67 meter transmitting whip antenna located at a distance of 100 feet and radiating 1 KW (kilowatt) of rf power. The reduction in maximum coupled voltage to the electrically small antennas is the order of 26 dB relative to the conventional antenna.

The noise factor, \( f_0 \), defining sensitivity of the receiving system using the electrically small antenna was determined [2], and is given in Figure 2 as a function of frequency. The dotted curve in the Figure describes expected shipboard quasi-minimum atmospheric noise [3] factor, \( f_0 \). Assuming that a 3 dB degradation in operating noise factor (\( f_0 = f_0 \approx 10 \)) by the addition of noise power from a real receiving system is acceptable, it is seen in Figure 2 that the sensitivity of the electrically small antenna receiving system essentially meets the assumed criterion at all frequencies. That is, external noise and system noise powers are equal.

Therefore, use of the electrically small antenna offers the possibility of significantly reducing coupled EMI between collocated
shipboard transmitting and receiving antenna systems. It is also
evident that adequate sensitivity can be achieved with the electrically
small antenna receiving system.

Although a significant reduction in EMI levels is obtained by
small antenna system approach, it is clear that even greater reduc-
tions are necessary in a viable receiving system approach. Adaptive
interference cancellation (AIC) introduced at the electrically small
receiving antenna feedpoint can provide additional EMI reduction.
AIC systems have been developed for narrow band use [4], but there
are no known systems that have wideband AIC capability. Since AIC
over wide bands requires control of phase as well as amplitude,
studies are being made to determine the characteristics of the EMI
channel over wide bands. Computer-aided design techniques embodied
by the "method of moments" in the Antenna Modeling Program [5] are
being used to determine channel EMI amplitude and phase response as
a function of frequency. EMI phase response at the receiver input
corresponding to amplitude response of the electrically small antenna
channel shown in Figure 1 is given in Figure 3. The dashed curve is
the channel free space delay. The channel amplitude and phase re-
sponse characteristics are useful in determining design criteria for
wideband AIC systems, and are being used as input data for testing
computer simulated AIC network designs.

Although the electrically small receiving antenna considered in
the analyses is a short top-loaded monopole, other antenna configu-
rations can be considered for the wide band receiving application.
For example, the receiving system noise factor is a function of the
open circuit noise voltage and short circuit noise current character-
istics at the receiver device input and the source antenna impedance.
Since $f_s$ is a fixed design parameter (assumed to be equal to quasi-
minimum atmospheric noise for a 3 dB degradation in operating noise),
devices having very low noise characteristics can be balanced against
the impedance values of other antennas configurations to obtain a
system noise factor equal to but no better than that required by the
3 dB degradation criterion. Minimum device noise levels would permit
minimum antenna electrical size, thereby minimizing local EMI coupled
to the receiving system. Loops, folded monopoles, and inductively
loaded monopoles might be considered as candidates.

The electrically small antenna also offers facility in receiving
antenna location on the ship structure. Transmitter/receiver separa-
tion may be increased compared to that possible with conventional
antennas. Advantage may be taken of the ship structure to screen the
receiving antenna from the transmitting antenna. Small antennas can
be used to permit adaptive receiving antenna array development. Com-
puter-aided theoretical analyses of electrically small receiving
antenna arrangements on simple ship structures are being made to
quantitatively assess radiation characteristics as well as local trans-
mmit/receive channel coupling characteristics.


Fig.1. Transmit/Receive channel amplitude characteristics. Spacing = 30.48 meters; radiated power = 1000 watts.
Fig. 2. Electrically small receiving antenna system noise and gas-minimum atmospheric noise factors.

Fig. 3. Channel phase response. Electrically small receiving antennas 30, 45, and 60 m whip transmitting antenna.

NOISE FACTOR, $10 \log_{10} f_s$

PHASE, (DEGREES)

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