MICROCOPY RESOLUTION TEST CHART

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A MININEC MODEL OF

THE MINILOOP ANTENNA

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ABSTRACT

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INTRODUCTION

In general, HF antennas mounted on ships will couple into metallic parts of the ship. This means that strong RF currents can be excited on closely coupled conducting surfaces, which in turn re-radiate. The total near field is the (vector) sum of the fields radiated by the antenna, the deliberate antenna, and the non-deliberate antennas. Re-radiation is enhanced whenever the non-deliberate antennas are similar in size to the deliberate antennas, or whenever resonant length conducting paths and spacings occur.

A computer model can be used to include the deliberate and non-deliberate interactions to accurately predict the near fields on exposed weather decks. This usually involves creating a wire grid model of all conducting surfaces. A wire grid model consists of a mesh of closely spaced, connected wires, which are close enough together to approximate a solid conducting surface. Building a wire grid model of a ship is a time consuming, tedius process, requiring detailed blue prints and considerable experience. The resulting computer model requires the resources of a large main frame computer system.

In some cases, a simplified antenna model may be used to avoid the expense of wire grid models. This requires good judgement and usually some additional information, such as measurements of the antennas in similar shipboard environments. The simplified model provides an upper bounds on the fields and the measurements are used to determine a suitable safety margin.

The first step is to develop and validate, if possible, a model of the antenna. This is a process of deciding how many wires and segments are required to achieve acceptable accuracy. This process will be described for the development of a MININEC model of the Miniloop antenna.

BACKGROUND

The "Mini" Numerical Electromagnetics
Code, or MININEC (reference 1), is a method
of Moments computer program for analysis of
thin wire antennas . A Galerkin procedure is
applied to an electric field integral
equation to solve for the wire currents.
This formulation results in an unusually
short computer program suitable for
implementation on a microcomputer. Hence,
MININEC is written in a BASIC language
compatible with many popular microcomputers.

MININEC solves for impedance and
currents on arbitrarily oriented wires,
including configurations with multiple wire
junctions, in free space and over a perfectly
conducting ground plane. Options include
lumped parameter impedance loading of wires
and calculation of near zone and far zone
fields. Both near electric fields and near
magnetic fields can be determined for free
space and over a perfectly conducting
ground. The far zone electric fields and
radiation pattern (power pattern) can also be
determined for free space and perfectly
conducting ground.

The miniloop is a single turn, HF loop
antenna which has been used for
communications by the U. S. Coast Guard for
both transmit and receive. It features
capacitive remote tuning and inductive feed.

The are two versions of the Miniloop
antenna (see reference 2). Version MLA-1/E
is for use in the band from 1.8 MHz to 14.5
MHz. Version MLA-2/D is for use from 3 MHz
to 24.5 MHz. Both consist of a large loop
mounted on a pedestal. The loop is excited
from a much smaller feel loop and turned via
a variable capacitor at the top of the large
loop. Figure 1 illustrates the basic
configuration.

THE MININEC MODELS

For MININEC, the main loop of the
Miniloop antenna is represented by a series
of one segment wires connected end to end to
form the main loop. A convergence test is
performed to determine the number of wires or
segments required for reasonable accuracy.

The impedance of the Miniloop is not
known. Referring to the open literature, a
loop whose characteristics are well
established is chosen. Figure 2 shows the
convergence test for a one wavelength
circumference loop in free space. The
admittance given by R.W.P. King (from
reference 3) is used to measure
convergence. Based on this data, a 22
segment or 22 sided polygon model of the loop
is selected. Figure 3 shows the performance
of this model over a wide band of
frequencies. Figure 3 is a comparison of the
MININEC model to the published data by R.W.P.
King. The Miniloops are used in the region
below the first self resonance. It is seen
in Figure 3 that the MININEC model tracks the
theory very well below resonance.

Using the MININEC loop model, the
Miniloop configuration of Figure 1 was
explored further. It has been determined
that the currents on the mast support are two
orders of magnitude lower than the loop
currents. The mast can therefore be removed
from the model without loss of accuracy.
Likewise, the feed loop can also be removed
from the model. The feed loop serves the
purpose of impedance matching and does not
contribute significantly to the properties of
the RF fields. Hence, the loop model is
simplified to a circular loop over a
perfectly conducting ground plane. For each
version of the Miniloop, the diameter of the
loop model is adjusted to give the same area
as the Miniloop version, i.e., the loop model
has the same self resonance as the Miniloop
version

Both versions of the Miniloop use a vacuum capactor located at the top of the large loop to tune the antenna to resbnance at the operating frequency. The MININEC model must be exercised once at each desired frequency to determine the value of reactance required for tuning. The model is excited or fed at the load point. The negative of the reactance of the antenna input impedance is the required load value. A second run with this reactance at the load point, but fed at the bottom of the loop, is generally done to verify the tuned condition.

MINILOOP EFFICIENCY

One way to determine the radiation efficiency of an antenna system is as follows:

The system efficiency is:

$$n = \frac{BW_o}{BW_m}$$

where BW_o is the ideal bandwidth from the MININEC model and BW_m actual bandwidth achieved or measured. The bandwidth of the Miniloops on a ground plane has been previously measured by NAVOCEANSYSCEN. The results from references 2 and 4 are given in figure 4.

The ideal bandwidth is determined from the MININEC model and the Q as follows:

$$BW_o = \frac{f_o}{Q_o}$$

Where the f_o is the operating frequency and Q_o is the ideal Q determined by the slope-reactance technique given in Jasik (reference 8). To apply this technique, the change in reactance of the tuned antenna is determined for a small change in frequency, and the Q is determined from

$$Q_o = \frac{\mid X_a \mid + f_o \mid \frac{dX_a}{df} \mid}{2R}$$

Where X_a is the antenna reactance and R is the radiation resistance at the frequency f_0. Figure 5 shows the efficiency versus frequency for the two Miniloop antennas as determined by this procedure.

SUMMARY

The process for development and validation of a MININEC model has been illustrated. In this case the Miniloop model has been used to determine antenna efficiency, which in turn can be used to set power levels for RF near field predictions.

REFERENCES

1. NOSC TD 938, "The New MININEC (Version 3): a Mini-Numerical Electromagnetic Code", J. C. Logan and J. W. Rockway, Sep. 1986

2. Department of Transportation/U. S. Coast Guard, "Instruction Booklet for MLA-1/E and MLA-2/D Miniloop Antenna Systems", Electronics Engineering Division, U.S. Coast Guard Station, Alexandria, Va., 1 Mar. 1982.

3. R. W. P. King, "Tables of Antenna Characteristics", IFI/Plenum Data Corporation, New York 1971

4. NELC TD 317, "MLA-1 Miniloop Antenna: A Technical Evaluation", by J. L. Lievens and D. W. DuBrul, 10 May 1974.
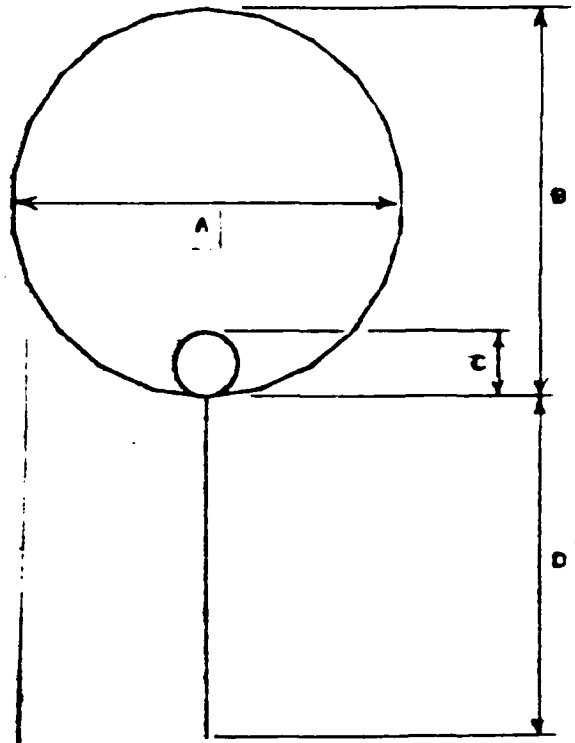
DIMENSIONS IN METERS

	MLA-D/2	MLA-E/1
A	1.9	2.1
B	.9	1.5
C	.18	.3
D	1.98	1.98

Figure 1. Illustration of basic Miniloop configuration

LOOP ANTENNA CONVERGENCE TEST

ADMITTANCE vs. NUMBER OF SEGMENTS

LOOP ANTENNA:

    LOOP CIRCUMFERENCE = 1.0 m

    WIRE RADIUS = 0.00674 m

    F = 299.8 MHz

RWP KING ADMITTANCE:

    $Y = G + jB = 5.2227 + j4.8875$ milliMHOS
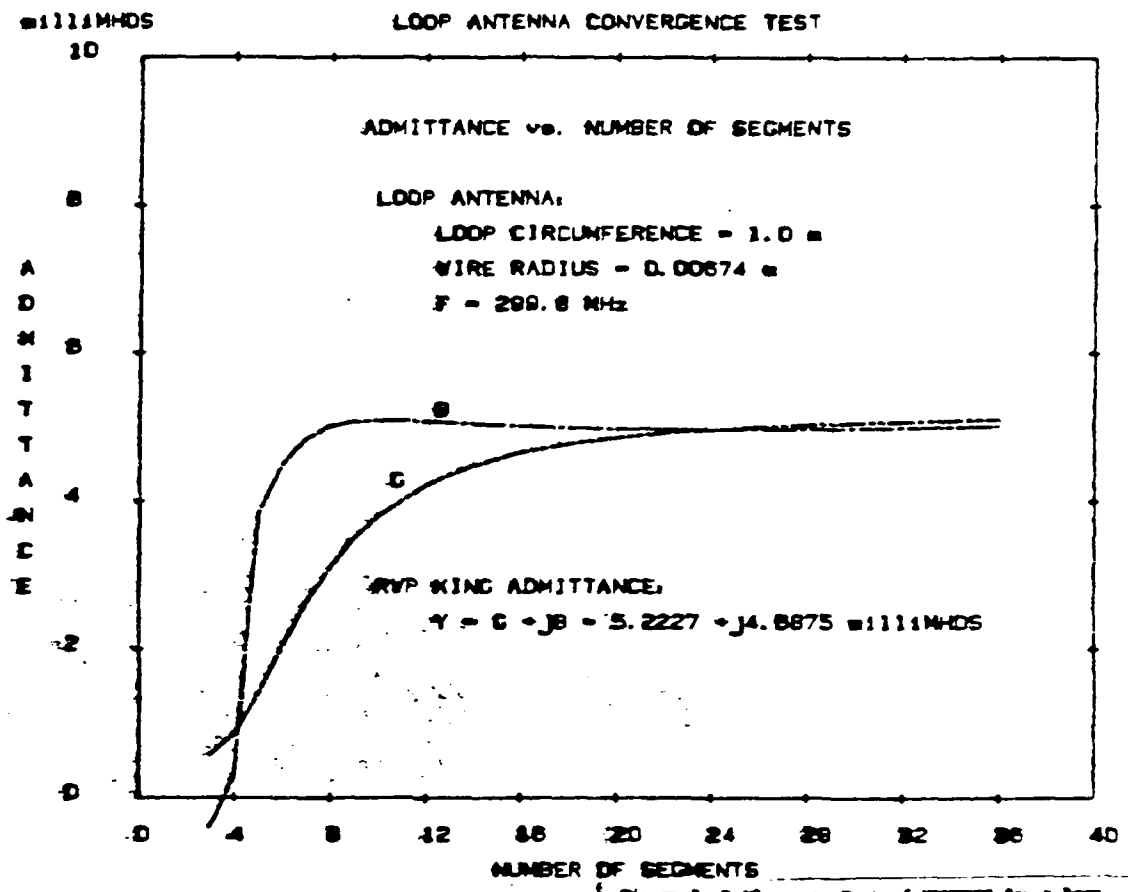
Figure 2. Convergence Test of NONNEC for a loop in free space

MININEC LOOP ANTENNA BEHAVIOR

AMITTANCE (Y= G + jB) vs. LOOP CIRCUMFERENCE

MININEC COMPARED TO RWP KING

LOOP ANTENNA:

LOOP TO WIRE RADIUS = 23.82 or

OMEGA = 2 ln(2 PI b/a) = 10

22 SIDE POLYGON (22 SEGMENTS)
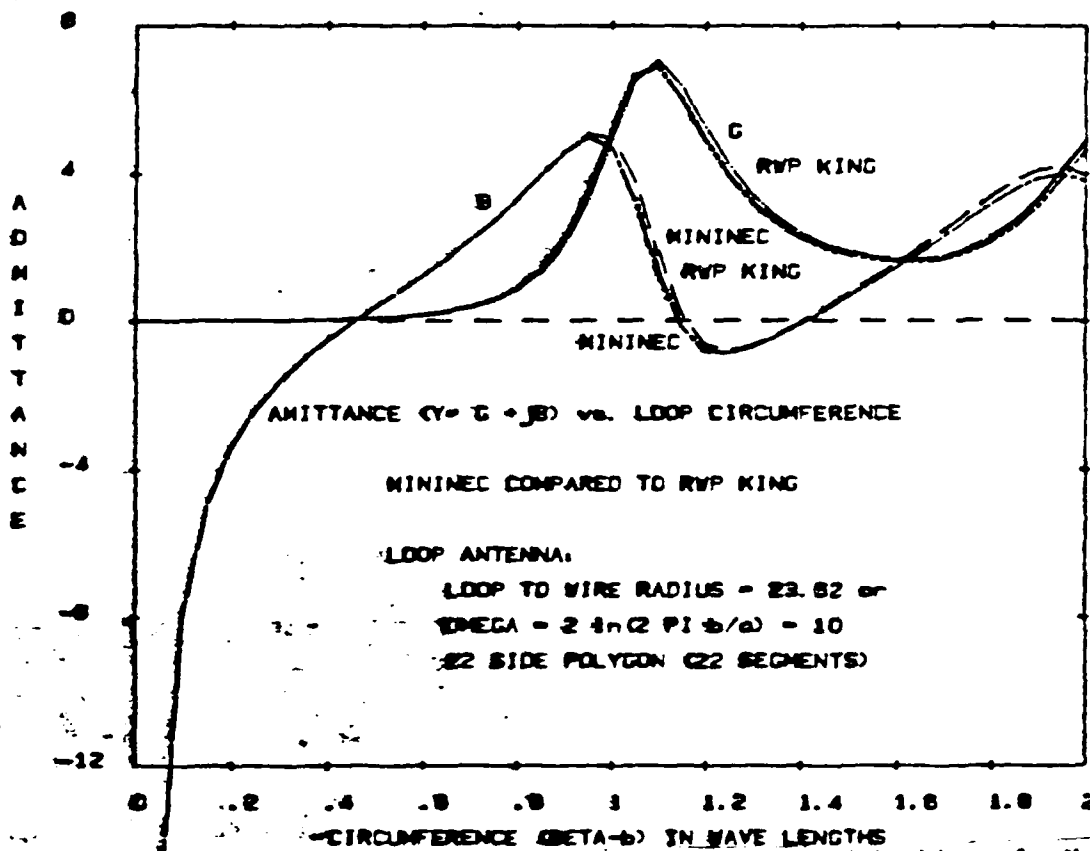
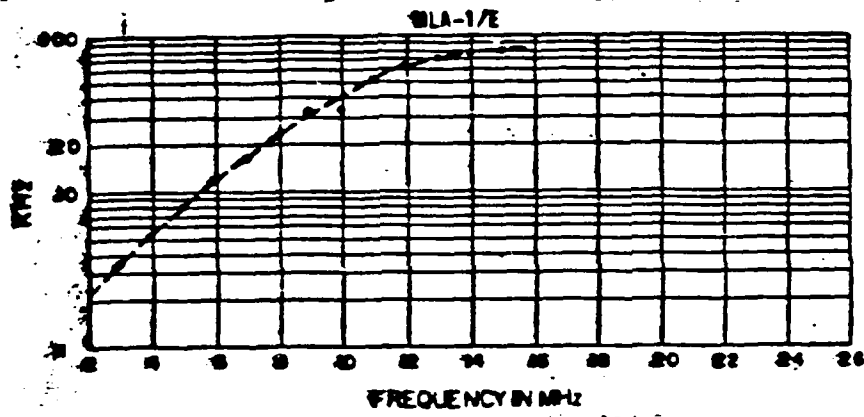Figure 3 Comparison of the admittance from the MININEC loop model to the theory of R.W.P. King (reference 7)
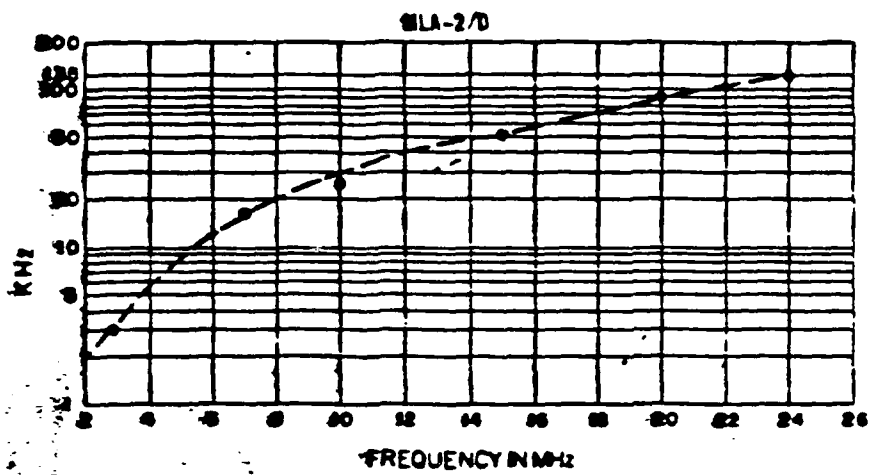
Figure 4 Half-power bandwidth measured on a
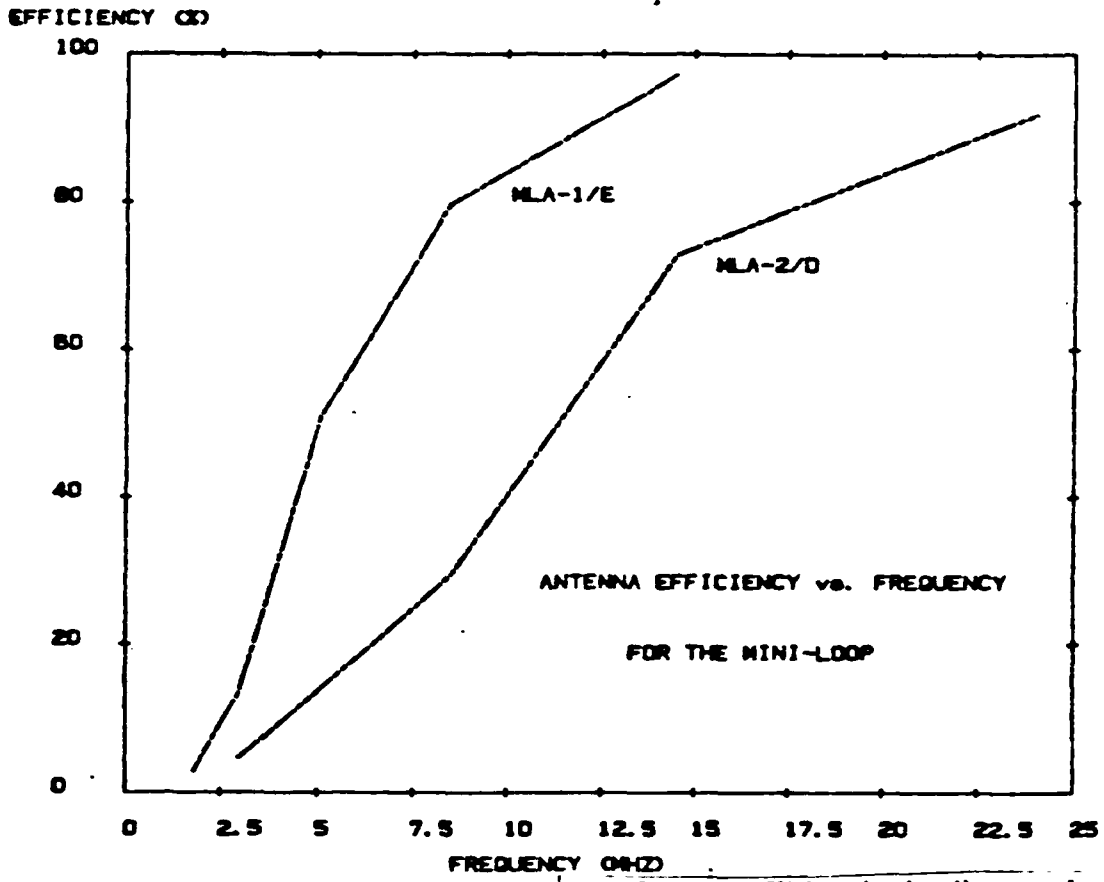ground plane

Figure 5 Miniloop efficiency based on the measured bandwidth and the KKKKNEC Model

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