MININEC APPLICATIONS GUIDE

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The Mini-Numerical Electromagnetics Code - MININEC has become very popular among amateur and professional antenna practitioners. Its widespread acceptance is due in no small part to its great versatility, user friendliness and extreme compactness which permits installation on PC's. Prior to MININEC, serious numerical modeling of antennas had to be accomplished primarily on mainframe computers. With MININEC, it is now possible to solve complex wire antenna problems in a conversational mode on a modest desk top computer, for example a PC having 64k of RAM. The present paper is concerned with application guidelines for MININEC. The input data set is discussed and numerical results are interpreted. A variety of illustrative linear antenna problems are worked out.

I. INTRODUCTION

The Mini-Numerical Electromagnetics Code-MININEC (Julian, Logan, Rockway, NOSC TD-516, 1982) has become very popular among amateur and professional antenna practitioners. With MININEC one can solve complex wire antenna problems in a conversational mode on a desk top computer. The present paper provides several supplemental worked out examples and information which elaborates on some of the original material for the benefit of the new user. The original MININEC document is out of print. However, a more recent version of MININEC is now available for those interested in details (Li, Rockway, Logan, Tam, "Microcomputer Tools for Communications Engineering," Artech House, Inc., 1983).

II. INPUT DATA

A. Geometry

Linear antennas are modeled by MININEC as one or more straight wires which may be located in free space or above perfectly conducting ground. The antenna geometry is set up by specifying the number of wires comprising the structure, the end point coordinates and radius of each wire, the number of segments in each wire, and connections between the various wires and to ground. Antenna excitation is specified after the geometry data is entered. Additional information is requested by the program concerning the frequency, impedance loading of wires, whether or not patterns are required and whether or not to print the currents.

In MININEC only straight wires are allowed. Bent wires are modeled by a sequence of straight wires. A wire is described by its radius and the x, y, z coordinates of its ends. Dimensions are in meters. The ground plane, if used, is the X-Y principal plane.

B. Segmentation of Wires

The number of segments in each wire is user specified when the antenna geometry data is entered. Each wire is then automatically divided by the code into equal length segments. The numerical solution for the currents is based on pulses (unknowns) centered at adjacent segment junctions.

A large number of segments (unknowns) will, in principle, lead to a more accurate solution. A curve can be prepared showing convergence of the current distribution or input impedance to a final value as the number of unknowns is increased within limits.

Numerical convergence of solutions is discussed in the original MININEC document. It is recommended that segmentation be varied to study the solution behavior. In some antenna problems coarse segmentation will suffice, for example in determining the qualitative behavior of antenna radiation patterns. To obtain accurate input impedance data, on the other hand, a large number of segments (unknowns, pulses) may be required.

C. Wire Connection Data

Wire connections are NOT automated in MININEC - connection data must be supplied by the user. Instruction for connection of wires is provided in the original documentation. However, the inexperienced MININEC user may become confused when entering wire connection data, especially when treating a complicated radiating system.

The MININEC wire connection rules are summarized in Fig. 1. An example of wire connection data is shown in Fig. 2. In Fig. 2 the wire ends are numbered. Connection data is shown inside the rectangular boxes.

Figure 1. MININEC WIRE CONNECTION RULES

Connection Data is required for each wire end after the wire end coordinates have been specified.

1. Proper connection requires identical coordinates for the end points of wires to be connected.

2. Zero elevation (Z=0) is required for wire connection to ground. The ground plane is in the X-Y principal plane.

3. Connection can only be made to a previously specified wire.

4. A zero indicates no connection (a free wire end).

5. A negative integer with magnitude equal to the wire number indicates a connection to ground.

6. Either end of a wire, but not both, may be connected to ground.

7. A negative integer with magnitude less than the wire number indicates that end one of the wire in question is connected to end one of an already defined wire ... or end two of the wire in question is connected to end two of an already defined wire.

8. A positive integer with magnitude less than the wire number indicates that end one of the wire in question is connected to end two of an already defined wire ... or end two of the wire in question is connected to end one of an already defined wire.

Example. If the wire is the first wire to be specified and end one is to be connected to ground, then -1 is used for the end one connection but 0 is used for the end two connection (even though end two may subsequently connect to another wire) because that wire has not yet been specified.

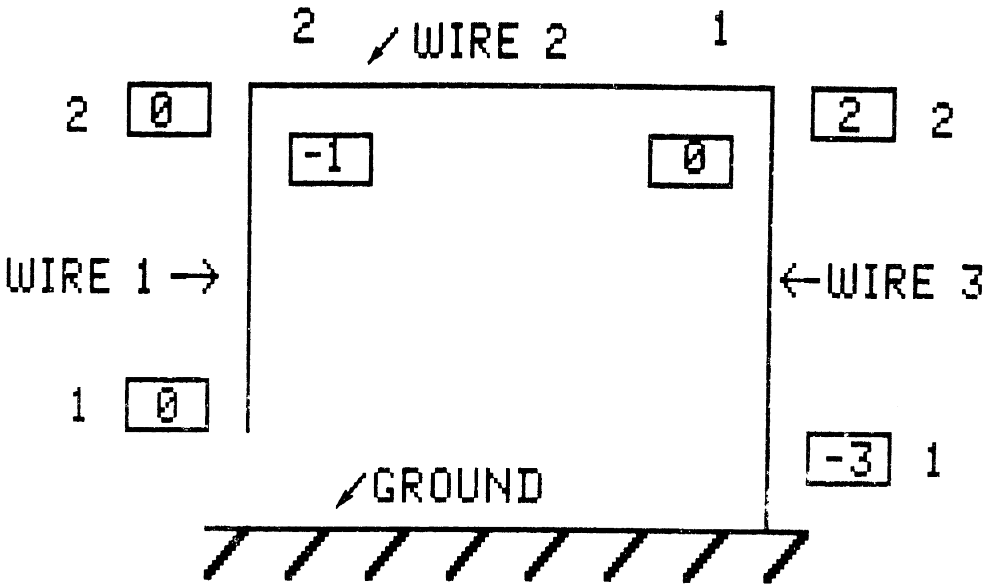


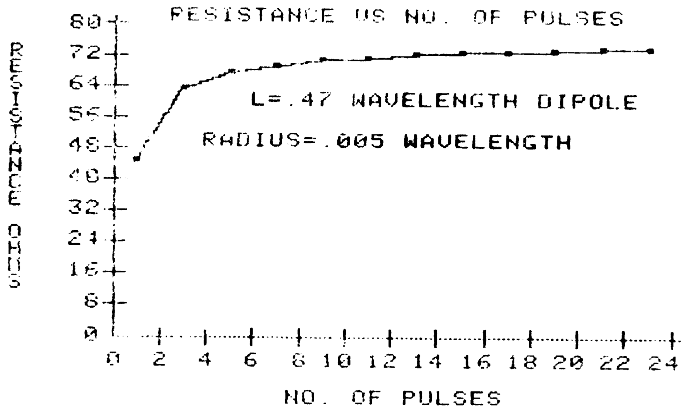
Figure 2.

III. SOME APPLICATIONS OF MININEC

A. Solution Convergence

In practice, accurate method-of-moments (MOM) solutions for antenna problems can be effected by allowing the number of unknowns (pulses, segments) to be sufficiently large within limits. The MOM solution procedure in MININEC employs pulse expansion functions and pulse testing functions. As such it is called a Galerkin method since the expansion functions and testing functions are the same.

A converged numerical solution can usually be realized with MININEC with only a moderate number of unknowns, depending on the problem. As an example, convergence of the input impedance to a final value is shown in Fig. 3 for a half-wavelength dipole antenna. For practical purposes, seven or nine pulses (unknowns) may suffice in this case.



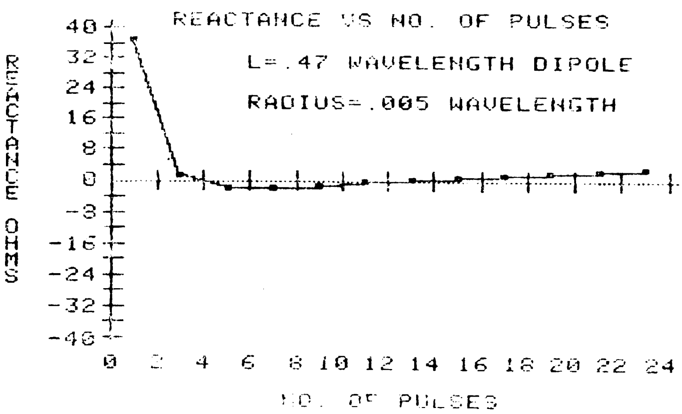


Figure 3.

In applying MININEC to a more complicated problem, some difficulty was experienced in obtaining a converged (stable) solution for the impedance of a "Y" antenna fed against ground. See Fig. 4. In this case fine segmentation was required to obtain convergence. Also, as the wire radius was decreased, even more segments were required.

The "Y" antenna was modified so that the wires intersect at right angles, as shown in Fig. 5. Convergence was then obtained with fewer unknowns.

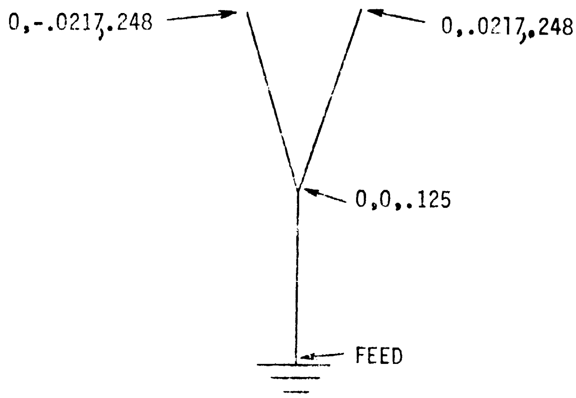
The difficulty in securing convergence of MININEC in problems involving closely-spaced connected wires is under investigation and is mentioned here as a caution for users. It is expected that coding modifications will alleviate the need for excessive segmentation in problems of this sort.

B. Comparison of Measured and Computed Admittance

As part of the validation process, the admittance of a monopole antenna measured on a large ground plane was compared with the computed admittance. See Fig. 6. In trying to reconcile the results, it was found that a shift in susceptance occurred due to 10 picofarads capacitance added by the connector in the measuring set up. The equivalent circuit of the test set up is shown in Fig. 7. When this effect was accounted for, excellent agreement was obtained as seen in Fig. 8. Other validation data is discussed in TD-516.

f=299.8 MHz

WIRE RADIUS (m) a	30 SEGMENTS (10 per wire) Z ohms	45 SEGMENTS (15 per wire) Z ohms	60 SEGMENTS (20 per wire) Z ohms
.000001	2.83-j2906	4772-j22334	292.7+j2933.2
.00001	158.7+j868.5	79.9+j377.9	67.48+j281.23
.0001	63.25+j177.6	60.2+j157.8	
.001	62.9+j99.7	63.3+j99.1	



CONVERGENCE TEST - MININEC

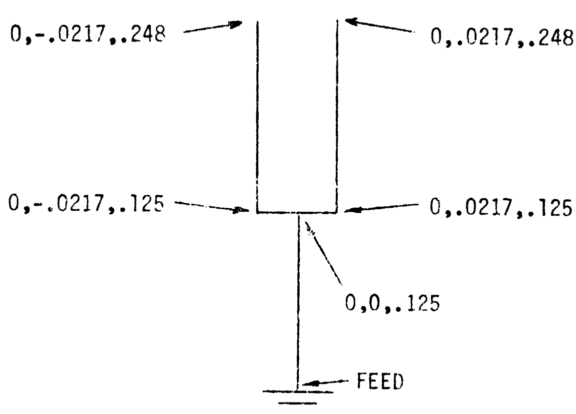
15 Dec 83
USACECOM

Y - junction of wires

Figure 4.

f=299.8 MHz

WIRE RADIUS (m) a	17 SEGMENTS (5,5,5,1,1) z ohms	40 SEGMENTS (12,12,12,2,2) z ohms	60 SEGMENTS (18,18,18,3,3) z ohms
.000001	48.59+j878.4	52.16+j526.4	53.28+j434.63
.00001	51.05+j214	54.42+j213.03	55.24+j216.83
.0001	52.96+j142.12	56.04+j161.02	56.91+j165.57



CONVERGENCE TEST - MININEC

15 Dec 83
USACECOM

90-degree wire junction

Figure 5.

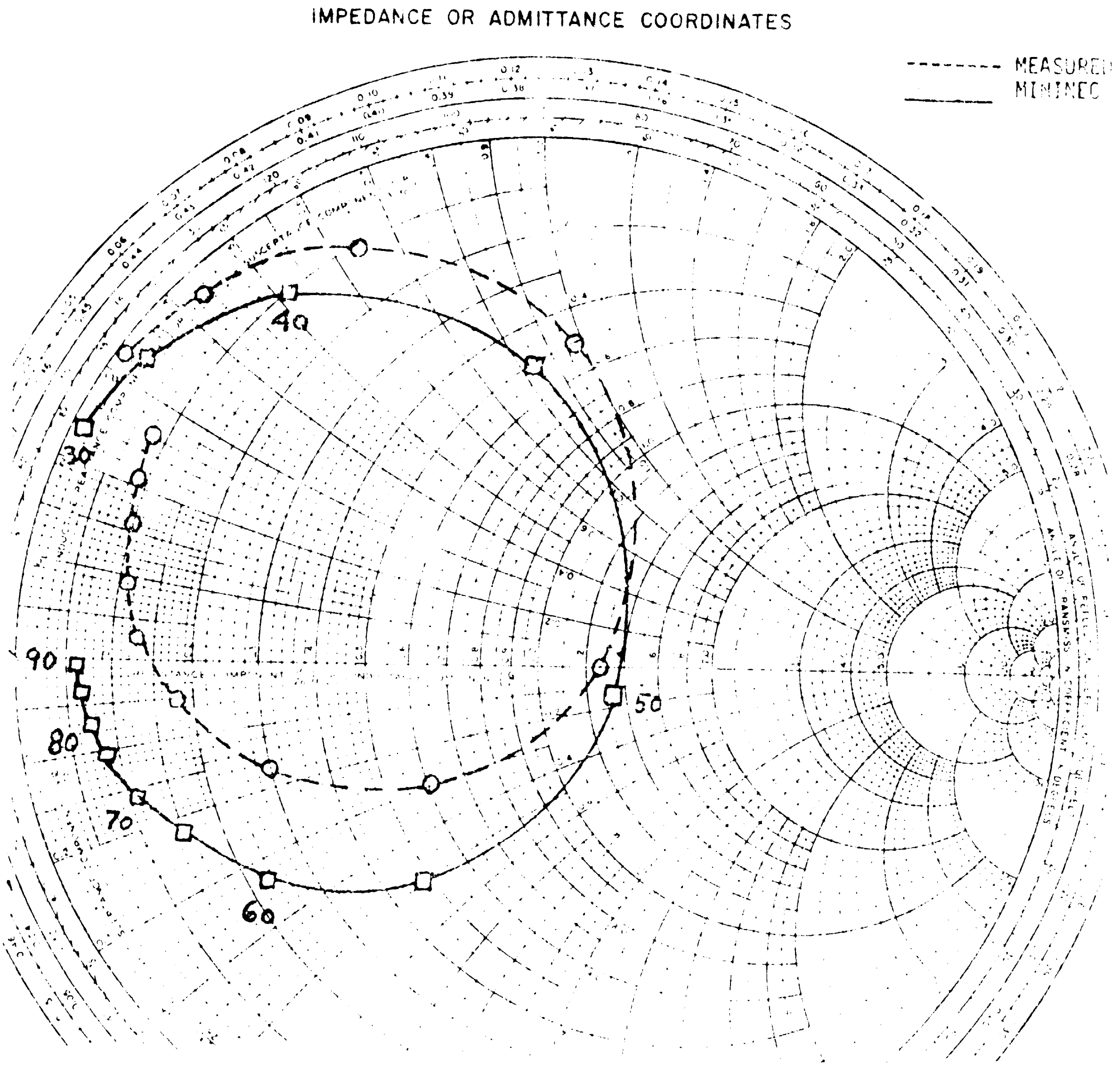


Figure 6.

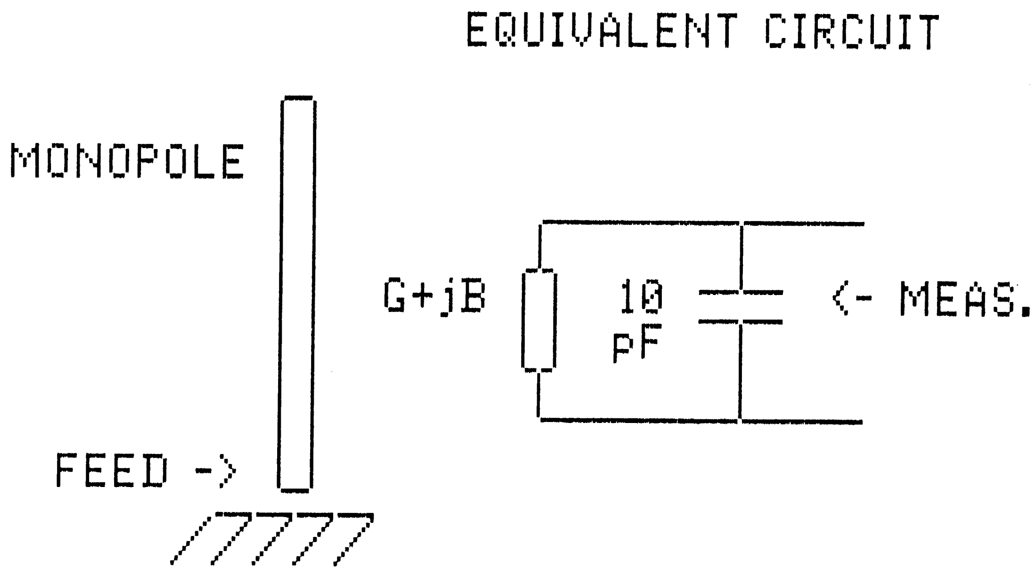


Figure 7.

IMPEDANCE OR ADMITTANCE COORDINATES

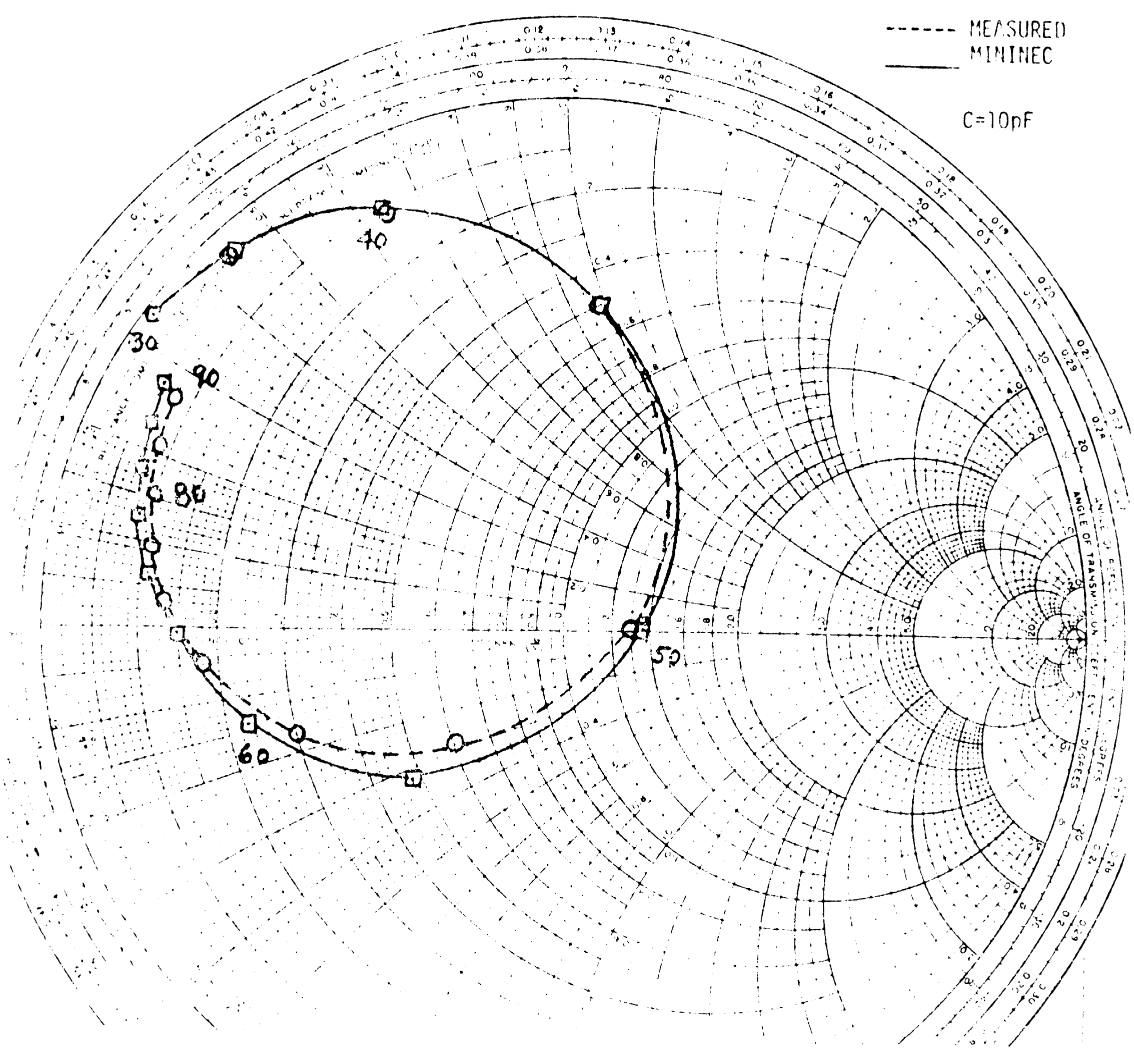


Figure 8.

C. Suppression of Parasitic Currents on Antenna Feed Lines

Parasitic rf currents may be induced on the outer surface of coaxial cable transmission lines and metal supports of an antenna system. These extraneous currents can degrade antenna performance and cause it to behave unpredictably with changes in the operating frequency.

MININEC was used to investigate the parasitic rf currents on a feed line located near a vertical half wave dipole configured as shown in Fig. 9. The calculated current distribution is shown in Fig. 10.

The amplitude of the parasitic currents can be significantly reduced by inserting high impedance reactive loads in series with the feed line. Suppression can be accomplished in a narrow frequency band by connecting a quarter-wave detuning stub to the feed line. Current can also be suppressed over an octave bandwidth or more by inserting a sequence of cable chokes in the feed line at quarter-wave intervals as shown in Fig. 11. A cable choke may consist of coaxial cable wound on a helical or toroidal core to form a high impedance reactor. A VHF cable choke, for example, can provide 500 ohms or more reactance between 30 to 90 MHz.

The current distribution on the feed line with a sequence of cable chokes inserted is shown in Fig. 12. The parasitic currents are essentially eliminated by this technique. In effect, the chokes act as a band-elimination filter for the rf currents allowing the antenna to operate as if the feed line were not present. In the MININEC model, the chokes are treated as point load reactors connected in series with the "wire" representing the feed line. The wire diameter equals that of the coaxial cable transmission line outer conductor. This example illustrates the loaded wire option available in MININEC.

IV. REVISIONS TO MININEC

Since its publication in 1982, MININEC has been revised several times to incorporate enhancements generated at NOSC and by other users. The known revisions and enhancements are listed in Fig. 13. The version of MININEC contained in the book (Artech House, Inc.) incorporates all of these revisions except for the modification allowing wires with a single pulse (unknown).

V. CONCLUSION

MININEC has proven to be a very versatile and widely accepted MOM code. The supplemental information and several examples provided here should be helpful to new users of MININEC.

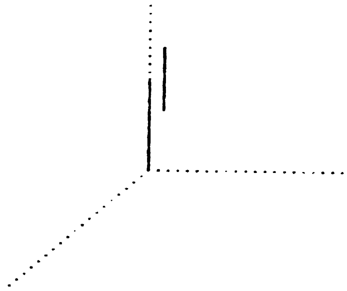


Figure 9.

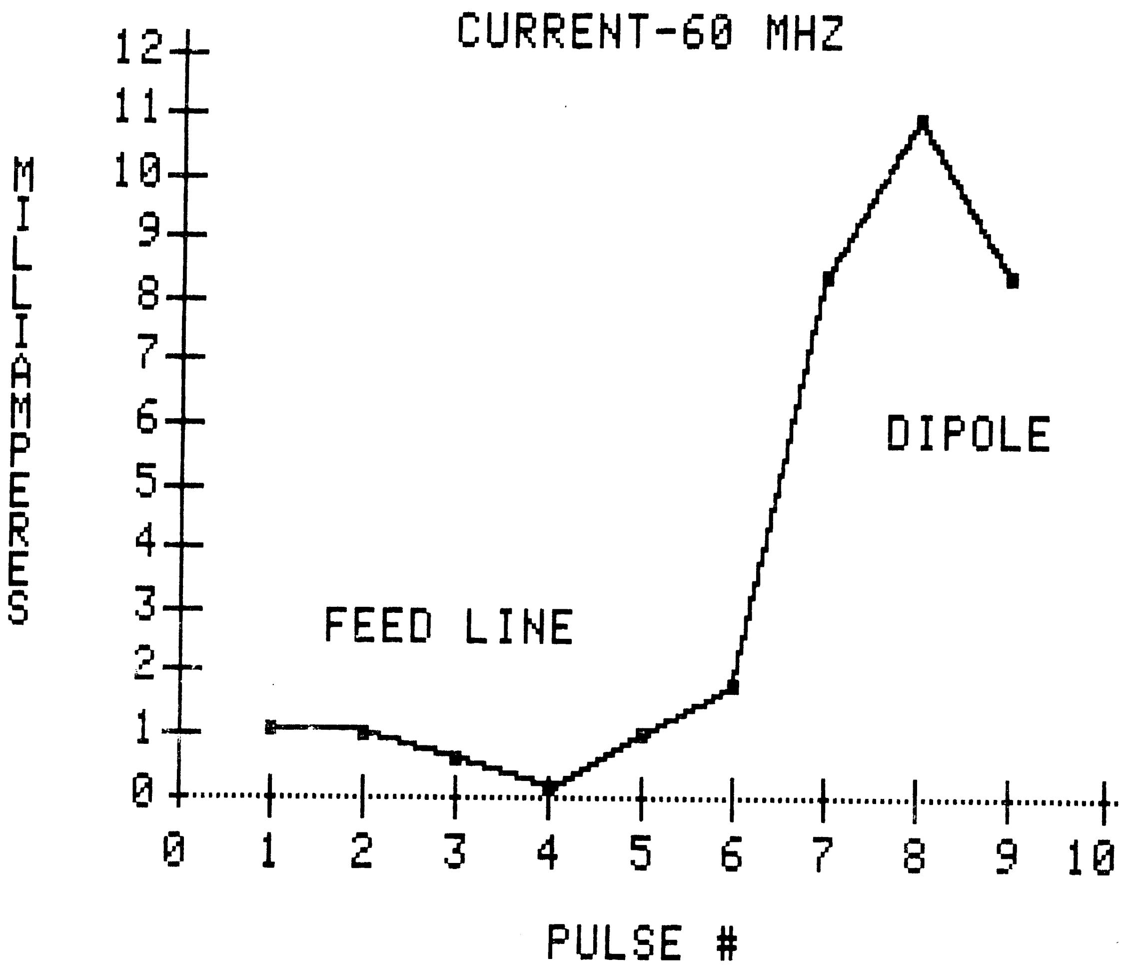


Figure 10.

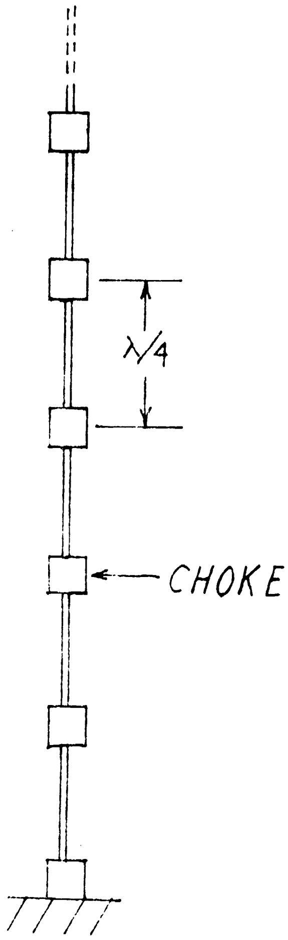


Figure 11.

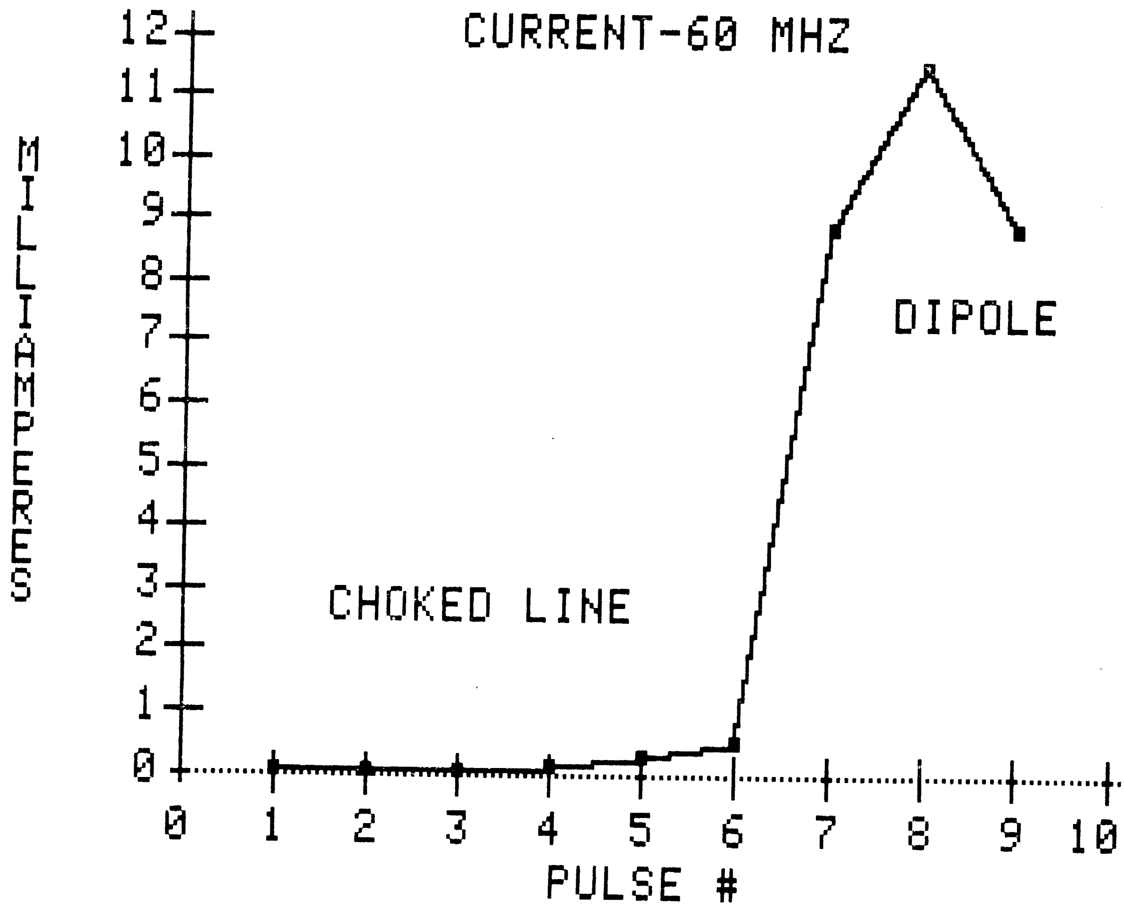


Figure 12.

MININEC

DOCUMENT	DATE	TITLE	DESCRIPTION
TD516	9/6/82	MININEC: A Mini-Numerical Electromagnetics Code	Original Tech Report & Code
MEMO	3/14/83	Enhancement of MININEC Capabilities	Wires inserting ground plane at any angle
MEMO	3/17/83	Lumped-Parameter Impedance Loading Option in MININEC	a. Load and feed collocated at base of monopole b. Corrects last constant in DATA
MEMO	4/25/83	Corrections in MININEC	Corrects pattern calculation
TN-EMC-84-02	3/12/84	"Bugs" in Geometry Section of MININEC	Modification allowing wires with single pulse

Figure 13.