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Technical Memorandum

APPLICATION OF NOMOGRAPHS FOR ANALYSIS AND PREDICTION OF RECEIVER SPURIOUS RESPONSE EMI

by

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23 July 1985

NAVAL AIR TEST CENTER
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NAVAL AIR TEST CENTER
PATUXENT RIVER, MARYLAND 20670-5304

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The traditional methods of predicting receiver spurious response EMI have produced volumes of test data points. To test all the data points would consume more test time than is normally available for electromagnetic compatibility (EMC) testing. This Technical Memorardum describes an analysis technique that has been developed to graphically depict all receiver spurious responses using a nomograph and permit selection of optimum test frequencies. The Technical Memorandum was prepared from a paper with the same title inserted at the 1984 IEEE-EMC symposium at Wakefield, Massachusetts.

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Spurious response EMI for the front end of a superheterodyne receiver follows a simple mathematic formula; however, the application of the formula to predict test frequencies produces more data than can be evaluated. An analysis technique has been developed to graphically depict all receiver spurious responses using a nomograph and to permit selection of optimum test frequencies. The discussion includes the math model used to simulate a superheterodyne receiver, the implementation of the model in the computer

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program, the approach to test frequency selection, interpretation of the nomographs, analysis and prediction of receiver spurious response EMI from the nomographs, and application of the nomographs. In addition, figures are provided of sample applications. This EMI analysis and prediction technique greatly improves the Electromagnetic Compatibility (EMC) test engineer's ability to visualize the scope of receiver spurious response EMI testing and optimize test frequency selection.

SUMMARY

Spurious response EMI for the front end of a superheterodyne receiver follows a simple mathematic formula; however, the application of the formula to predict test frequencies produces more data than can be evaluated. An analysis technique has been developed to graphically depict all receiver spurious responses using a nomograph and to permit selection of optimum test frequencies. The discussion includes the math model used to simulate a superheterodyne receiver, the implementation of the model in the computer program, the approach to test frequency selection, interpretation of the nomographs, analysis and prediction of receiver spurious response EMI from the nomographs, and application of the nomographs. In addition, figures are provided of sample applications. This EMI analysis and prediction technique greatly improves the Electromagnetic Compatibility (EMC) test engineer's ability to visualize the scope of receiver spurious response EMI testing and optimize test frequency selection.

APPLICATION OF NOMOGRAPHS FOR ANALYSIS AND PREDICTION OF RECEIVER SPURIOUS RESPONSE EMI

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Abstract

Spurious response EMI for the front end of a superheterodyne receiver follows a simple mathematic formula; however, the application of the formula to predict test frequencies produces more data than can be evaluated. An analysis technique has been developed to graphically depict all receiver spurious responses using a nomograph and to permit selection of optimum test frequencies. The discussion includes the math model used to simulate a superheterodyne receiver, the implementation of the model in the computer program, the approach to test frequency selection, interpretation of the nomographs, analysis and prediction of receiver spurious response EMI from the nomographs, and application of the nomographs. In addition, figures are provided of sample applications. This EMI analysis and prediction technique greatly improves the Electromagnetic Compatibility (EMC) test engineer's ability to visualize the scope of receiver spurious response EMI testing and optimize test frequency selection.

Introduction

The Naval Air Test Center (NAVAIRTESTCEN) is the Navy's technical center for aircraft test and evaluation. The EMC section at NAVAIRTESTCEN Systems Engineering Test Directorate (SETD) conducts technical evaluations of aircraft for Electromagnetic Environmental Effects (E^3) specification compliance. As a minimum, all aircraft are specified to provide intrasystem EMC between all onboard avionics equipment. The RF subsystems are one group of equipment which require extensive evaluation. The RF equipments used on aircraft are usually integrated by the airframe company and, through the use of computer programs like Intrasystem Electromagnetic Compatibility Analysis Program (IEMCAP), design provisions for intrasystem EMC are considered. The design process considers all facets of the installation which would affect intrasystem EMC with the RF equipment. For example, the EMI coupled by RF propagation would consider transmitter power, transmitter antenna gain, path loss, receiver antenna gain, line losses, and receiver sensitivity. Computer programs like IEMCAP combine these considerations and guide the design on antenna placement, blanking, equipment isolation, and degree of EMC. The data is limited to those areas where the design is inadequate, outputting predicted receiver spurious response EMI, receiver intermodulation EMI, and associated EMI margins.

The EMC test engineer takes a different perspective on aircraft intrasystem EMC. Rather than design by EMC analysis, the perspective is testing to verify EMC analysis and design. The coupling calculated by the designer's computer programs must be tested along with the designed incompatibilities. The use of the IEMCAP (without the coupling model) as an analysis and prediction tool for testing has produced volumes of test data points. To test all the data points would consume more test time than is normally available for EMC testing. Therefore, at NAVAIRTESTCEN, specialized Test and Evaluation (T&E) computer programs have been written to test the EMC design and optimize the quantity of test data.

Math Model

The predicted receiver spurious response of superheterodyne receiver is one area analyzed by these computer programs. A single stage of a superheterodyne stage consists of a desired receive frequency range which is mixed with a local oscillator (LO) resulting in a new signal called an intermediate frequency (IF) as shown in figure 1. The block diagram in figure 1 is mathematically modelled by equation (1).

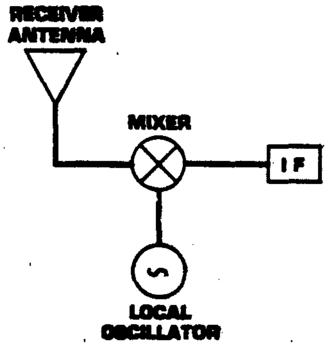


Figure 1. Block Diagram of a Single Stage of a Superheterodyne Receiver

$$Fr = \frac{(Pr \times Flo + Fif)}{Qr} \quad (1)$$

where:
- Fr = Receive Frequency
- Flo = Local Oscillator Frequency
- Fif = Intermediate Frequency
- Pr = Harmonic multiplier for Local Oscillator Frequency to receive Fr
- Qr = Harmonic multiplier for Receive Frequency to receive Fr

The value for the harmonic multipliers (Pr, Qr) is the quantities used in the design of the superheterodyne receiver to mix the desired signal into the IF range. The spurious response EMI which could occur is given in equation (2).

$$Fsr = \frac{(P \times Flo + Sif \times Fif)}{Q} \quad (2)$$

where:
- Flo = Local Oscillator Frequency
- Sif = Sign of the Intermediate Frequency may be +1 or -1
- P = Harmonic multiplier for the Local Oscillator Frequency
- Q = Harmonic multiplier for the Spurious Response Frequency

In equation (2), the value of the harmonic multipliers (P, Q) can be any whole number and the IF sign may be positive or negative (+ or -). These equations when implemented via computer programs can output many combinations of frequencies for an EMC test. Therefore, a means becomes necessary to view all the data at once and then make optimum selections of test frequencies. In reference 1, predicted receiver spurious response to EMI was shown using a nomograph. The nomograph concept was adapted as an analysis and prediction test tool for predicting receiver spurious response EMI. The computer program called Spurious Response Interference Graph (SPRIG) was developed using the equations to interactively plot the receiver spurious response EMI of one mixing stage of a superheterodyne receiver.

The Program

The program was initially written in FORTRAN 4 and hosted on a Hewlett Packard (HP) 8500 minicomputer RTE-II system using the RTE-11 operating system. Subsequently, the program has been rehosted on an HP 2113E minicomputer using the RTE-VI operating system and FORTRAN 66. The graphics is written to use the HP Graphics 1000, an HP 2648 graphics terminal equipped with an HP 2671G graphics printer peripheral.

The program structure is a top down design with the following sequential sections: initializing variables, interacting inputting of data, calculation of spurious responses, drawing of the graph, plotting calculated data, user menu, screen copy, input test data, read data from the graph, and victim prediction. There were eight subroutines developed to provide the repetitive function of determining frequency divisions for the graph, calculating receiver spurious responses using the victim frequency, calculating victim frequency using the source frequency, channelizing frequencies, displaying of the user menu, assigning of IF sign character, inputting data corrections, and calculating of axis in engineering units. The interaction of these program elements is shown in figure 2.

The initialization of the variables section sets up the matrices used in the program and initializes the HP 2671G printer and the HP 2648 graphics terminal.

The section to interactively input the equipment characteristics reflects the computer implementation of equations (1) and (2). The source transmitter range and channelization is inputted for the variable Fsr. The victim receiver range and channelization is inputted for the variable Fr. A maximum limit is inputted for the P,Q values. In order to input the actual if mixing product used in the superheterodyne receiver design and include the possibility of either an IF range or a fixed IF, the IF range is entered using the mathematical equivalent range of the IF. The final quantity entered is the harmonic multipliers (Pr,Qr) used in equation (1) to actually receive the desired signal. With the values of Fsr, Fr, P, Q, Pr, Qr, and IF range, the value for a fixed local oscillator (Flo) is calculated by the program using equation (3).

$$Flo = \frac{(Qr + Fr - Fif)}{Pr} \qquad (3)$$

where:
- Flo = Local Oscillator Frequency
- Fr = Minimum Receive Frequency
- Fif = Intermediate Frequency for the Minimum Receive Frequency
- Qr = Harmonic multiplier for the receive frequency used in the receiver
- Pr = Harmonic multiplier for the Local Oscillator used in the receiver

If the IF is fixed, then a flag is set in the program to permit an LO range and to recalculate the local oscillator (Flo) each time the victim receiver frequency changes. A sample of the above interactive input is shown in figure 3. The user is provided the option to obtain a hard copy of the entered parameters before proceeding to the graphics phase (see bottom of figure 7).

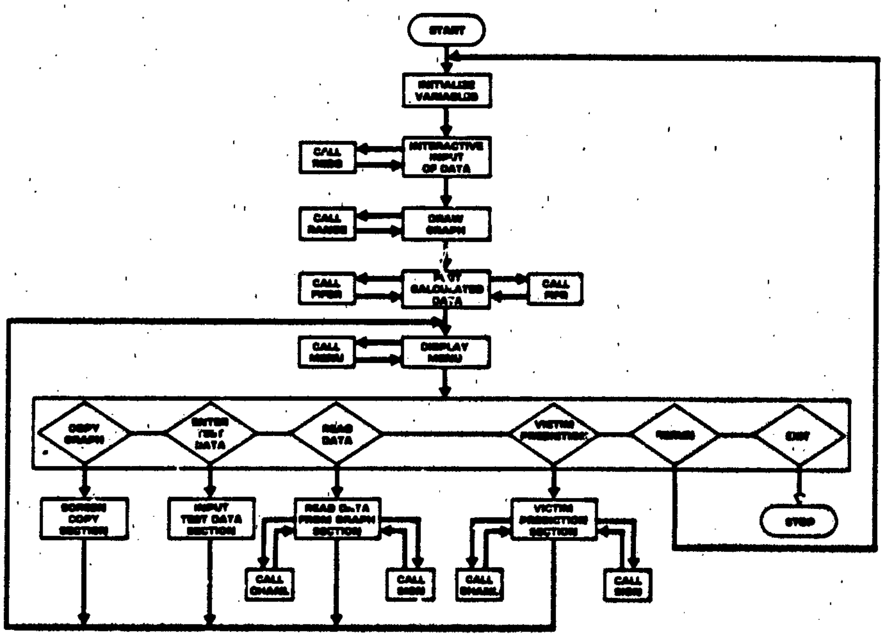


Figure 2. Interaction of SPRIG Program Elements

THIS PROGRAM WILL GRAPH THE SPURIOUS RESPONSE (Fsr) OF A VICTIM RECEIVER (Fr) WITH EITHER FIXED OR VARIABLE IFs DUE TO A SOURCE TRANSMITTER WHERE: Fsr = (P X Fs [+ / -] Fif) / Q
Fr = ((Pr X Fs) + Fif) / Qr

Push Return Key to Continue

DO YOU WANT A HARD COPY OF THE CALCULATED DATA?
ENTER YES OR NO
= > N

INPUT TRANSMITTER RANGE AND CHANNEL SPACING:

MINIMUM VALUE,MAXIMUM VALUE,INCREMENT
= > 296,362,1

INPUT RECEIVER RANGE (Fr):

MINIMUM VALUE,MAXIMUM VALUE,INCREMENT
= > 225,254,1

INPUT MAX VALUES FOR P AND Q:

P MAXIMUM VALUE,Q MAXIMUM VALUE
= > 5,5

INPUT I.F. RANGE (+ FOR POSITIVE MIXING, - FOR NEGATIVE MIXING):

MINIMUM VALUE,MAXIMUM VALUE
= > -60,-60

INPUT CO-CHANNEL INTERFERENCE VALUES FOR THE RECEIVER (Pr,Qr)

Pr VALUE,Qr VALUE
= > 1,1

INPUT GRAPH TITLE:

UHF TRANS. (S) VS UHF REC (V)

Figure 3. SPRIG Interactive Input

To develop the nomograph for spurious response EMI, the linear relationship of equation (2) was utilized. The changes in the values of the variables in equation (2) result in a straight line curve which extends across the range of the axis. Therefore, to plot the equation on the graph, only two sets of solutions to the equation are required to plot one curve across the graph. The algorithm used to produce the nomograph is shown in figure 4. The calculations start by attempting to find a solution for the equation which would be on the left side of the graph. A source frequency is calculated based on the minimum receive frequency, harmonic multipliers, and the IF sign. The subroutine which finds the frequency for spurious response using the victim frequencies (FIFSR) performs this calculation using the algorithm in figure 5. If the solution of the equation is in the range of the graph, then the data is plotted on the graph and the program sets up to solve for an end point at the bottom of the graph. The solution for the victim frequency is based on the minimum transmit frequency, harmonic multipliers, and IF sign. The subroutine which finds the receiver frequency for the victim receiver using the source frequency (FIFR) performs the calculation using the algorithm in figure 6. If the solution is in the range of the victim receiver, the end data point is plotted and labeled; otherwise, the program tries to find a solution on the left or topside of the graph. This process is continued for curves which start on the bottom side of the graph and end on the right or topside of the graph and those which start on the right side and end on the topside of the graph. After all possible solutions have been tried, then the IF sign is changed or the harmonic multipliers (P,Q) are incremented and the process is repeated. The program leaves this algorithm after the harmonic multipliers exceed the maximum entered value. At this point in the program, the user is presented with the display shown in figure 7 and permitted to select analysis and prediction options available through the menu subroutine.

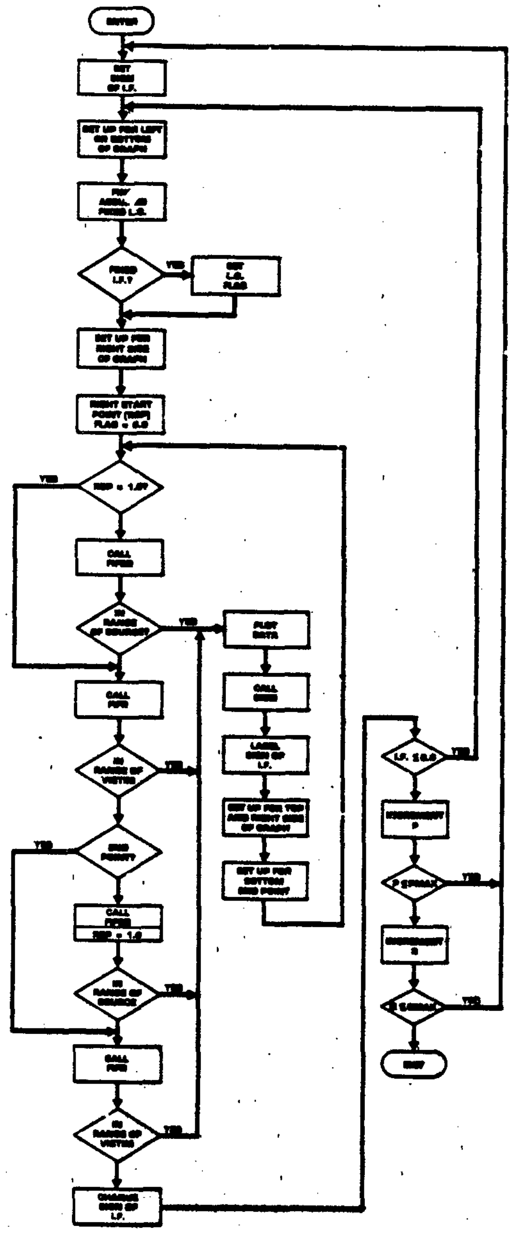


Figure 4. Nomograph Plotting Algorithm

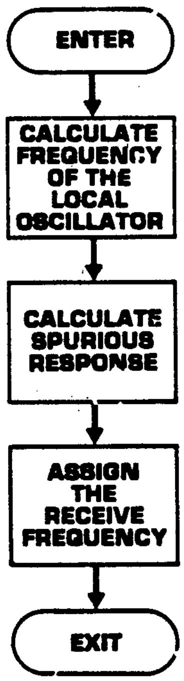


Figure 5. FIFSR Algorithm

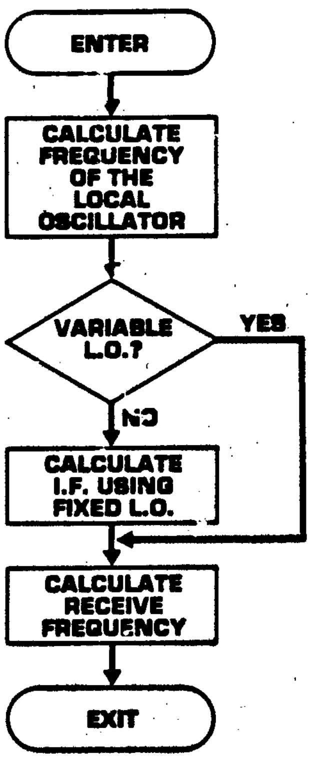
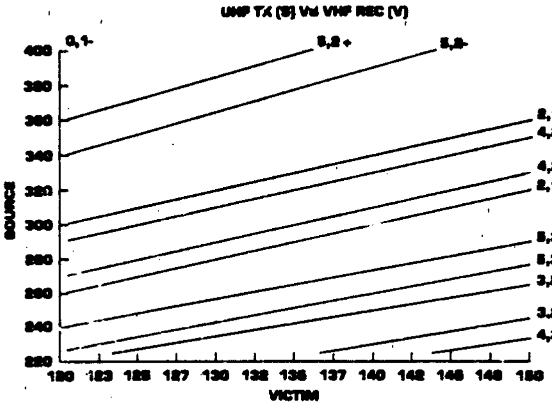


Figure 6. FIFR Algorithm



TEST DATA FOR GRAPH OF: UHF TX (S) VS VHF REC (V)

GRAPH TITLE	UHF TX (S) VS VHF REC (V)
TRANSMITTER MINIMUM VALUE	225.0
TRANSMITTER MAXIMUM VALUE	400.0
TRANSMITTER INCREMENT	.2500E-01
RECEIVER MINIMUM VALUE	120.0
RECEIVER MAXIMUM VALUE	1[illegible].0
RECEIVER INCREMENT	.2500E-01
P MAXIMUM VALUE	5.000
Q MAXIMUM VALUE	5.000
I.F. MINIMUM VALUE	-20.00
I.F. MAXIMUM VALUE	-20.00
P OF THE RECEIVER	1.000
Q OF THE RECEIVER	1.000

Figure 7. Receiver Spurious Response EMI Nomograph (Fixed IF)

The analysis and prediction options permit hard copy of the nomograph, entry and display of test frequency pairs on the graph, reading frequency pairs from the graph, and prediction of source frequencies based on a victim frequency. The programming of the options varies in difficulty. The hard copy of the nomograph was a simple raster dump from the HP 2648 graphic terminal to the HP 2671G printer. The option to enter and display frequency pairs on the graph follows the algorithm shown in figure 8. The fundamental operation is to plot the character "o" at the location of the entered frequency pairs. The option to read the frequency pairs from the graph consists of two operations (figure 9): first, the location of the screen curser is read from the display in coordinates relative to the graph. Then, a computational loop is entered to find a spurious response victim and source frequency pair which is close in value to the number read off the graph. Finally, the program recommends a test frequency pair and rounded down frequency channelized pairs by the subroutine CHANL. The output for this section is shown in figure 10.

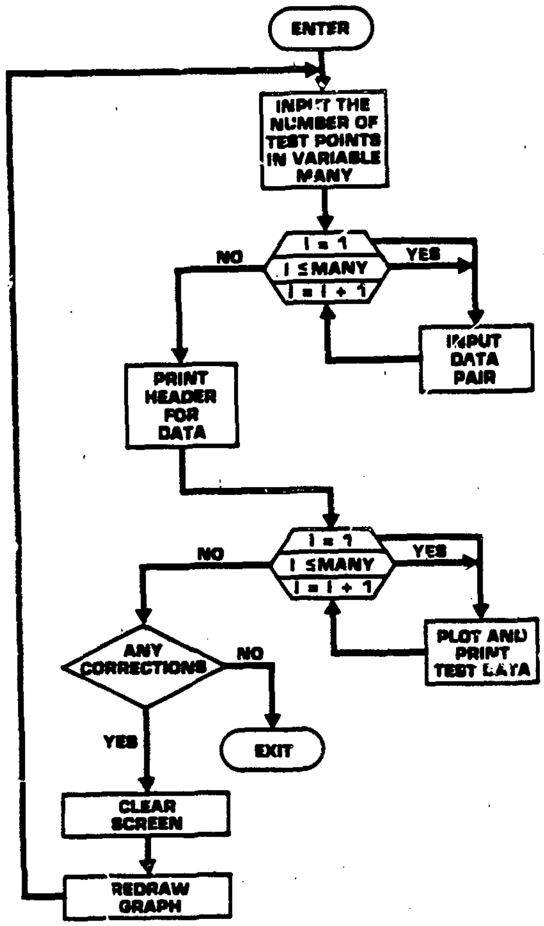


Figure 8. Algorithm to Enter Test Data

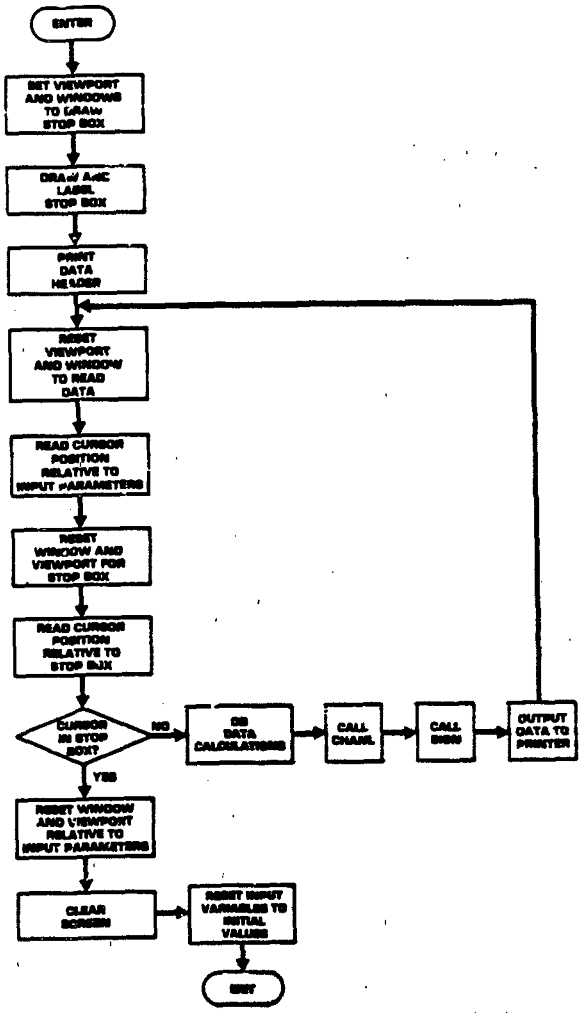
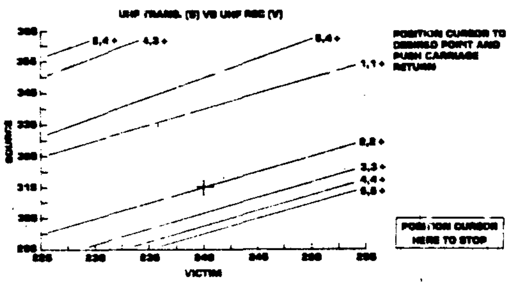


Figure 9. Algorithm to Read Data from the Graph



DATA FROM GRAPH OF: UHF TRANS. (S) VS UHF REC (V)

VICTIM FREQ	SOURCE FREQ	P	Q	I.F.	ERROR	TX CALCULATED
240.014	315.130	6	5	+	.130400	315.000

RECOMMENDED TEST CHANNELS:

VICTIM FREQ	SOURCE FREQ
240.000	315.000

Figure 10. Output from the Read Data from the Graph Section

The section to calculate the source frequency based on a victim frequency is diagramed in figure 11. The algorithm utilizes the user inputted victim frequency and calculates all possible spurious response EMI using equations (1) and (2). The resulting source frequency is rounded down to the nearest RF channel via the subroutine CHANL. A sample of the output for this section is shown in figure 12.

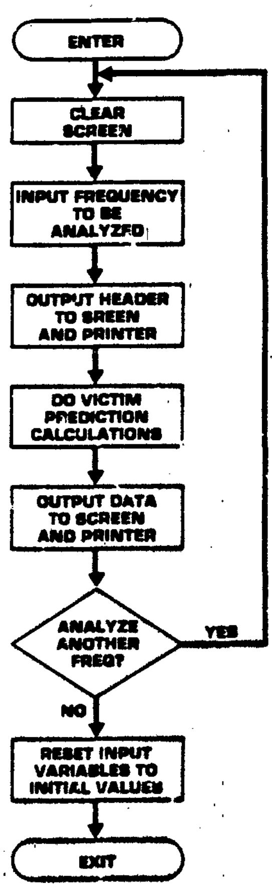


Figure 11. Victim Prediction Algorithm

ENTER VICTIM RECEIVE FREQUENCY TO BE ANALYZED: 241.257

VICTIM PREDICTION

VICTIM FREQ	SOURCE FREQ	P	Q	I.F.	SOURCE CHANNEL
241.257	341.257	1	1	+	341.000
241.257	316.257	2	2	+	316.000
241.257	307.924	3	3	+	307.000
241.257	303.757	4	4	+	303.000
241.257	351.571	5	4	-	351.000
241.257	301.257	5	5	+	301.000

DO YOU WANT TO ANALYZE ANOTHER FREQUENCY
YES OR NO? N

Figure 12. Output from Victim Prediction Section

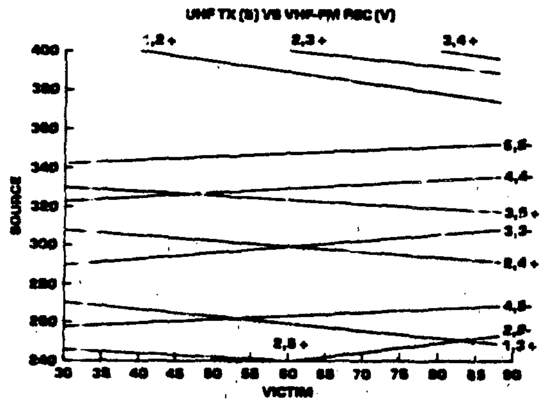
Once a user has completed exercising all the desired options, the program can be interactively rerun or programmed for a logical end.

Equipment Characterization

To apply the program, the test engineer must first characterize (model) the equipment to be evaluated. Source transmitters are typically either fixed frequency or transmit over a frequency range with a fixed minimum channel spacing. In the latter case, the source characteristics match the program input sequence; however, fixed frequency source transmitters should be modelled such that the fixed frequency is in the center of an arbitrary range which is determined by the channel spacing. For example, a transmitter fixed at 1 GHz could be characterized as a transmit frequency range of 999 to 1001 MHz, with 1 MHz channel spacing. The victim receivers are typically fixed frequency, single banded or multibanded superheterodynes, with either a fixed frequency first IF or a first IF range. Since the program can only calculate on one IF stage, multibanded receivers must be characterized as separate receiver bands for each unique first IF stage. Then, the receive range, channel spacing, and corresponding IF frequency or IF frequency range can be identified. Fixed receivers are characterized similar to fixed transmitters in that the fixed receiver frequency is centered over an arbitrary receive range which is determined by the channel spacing with a fixed IF. The SPRIG program requires an IF range (variable IF) to be inputted. To characterize a fixed IF, the same IF frequency would be inputted for both minimum and maximum IF values. To characterize whether the IF is designed for positive or negative mixing products, each IF value is given the sign (+ or −) of its mathematical range. It is assumed by the design of the computer program that the receiver range (minimum and maximum) matches the IF range (minimum and maximum). For example, at the minimum receive frequency, the IF will be at the minimum IF value inputted. If the receiver is not a superheterodyne and has no IF, but instead an envelope detector, then the receive range is also characterized as the IF range. The final area to be characterized is the co-channel interference values which are the harmonic multipliers of the local oscillator (P) and source frequency (Q). The values are the multiples used in the superheterodyne design to receive the desired receiver range. Typically, these multiples are one (P=1,Q=1). Once the source transmitter and victim receivers are characterized, the test engineer can use the SPRIG program for analysis and prediction of receiver spurious response test frequencies.

Analysis and Prediction Applications

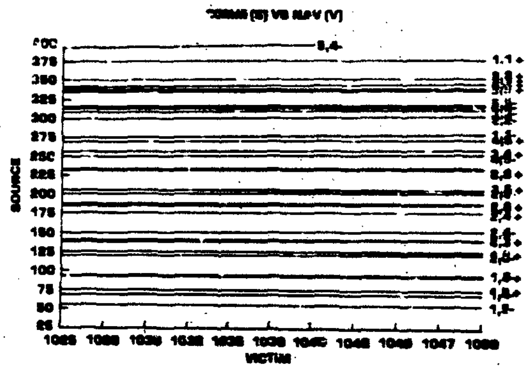
Two basic types of receiver responses can be analyzed: spurious responses and harmonic responses. The spurious response EMI prediction is shown in figure 13. The engineer viewing the nomograph display can visualize all possible receiver spurious response EMI and determine which curves need to be tested. If the display becomes too packed with curves (figure 14), then the engineer can interactively reduce the values for P,Q and immediately be able to reduce the clutter and analysis range (figure 15). The receiver spurious response EMI nomographs help visualize insignificant receiver spurious response predictions as shown in figure 16, or complex receiver spurious response predictions as shown in figure 17, where multiple spurs converge in one area. In cases where the RF equipment operates in the same frequency ranges, the co-channel interference curve is displayed as shown in figure 18. Harmonic response EMI are a subset of spurious response EMI. By limiting the value of the harmonic multiplier (P) of the local oscillator (Flo) to the co-channel interference value and setting the harmonic multiplier (Q) of the source transmitter (Fsr) to the highest harmonic to be displayed, the resulting graph is a family of curves for harmonic response EMI. The harmonic response predictions are shown in figure 19. The EMC test engineer may select test frequencies for transmitter harmonic emission testing or for victim receiver mixer harmonic response testing.



TEST DATA FOR GRAPH OF: UHF TX (S) VS VHF-FM REC (V)

GRAPH TITLE	UHF TX (S) VS VHF-FM REC (V)
TRANSMITTER MINIMUM VALUE	[illegible]0.0
TRANSMITTER MAXIMUM VALUE	400.0
TRANSMITTER INCREMENT	.2500E-01
RECEIVER MINIMUM VALUE	30.00
RECEIVER MAXIMUM VALUE	90.00
RECEIVER INCREMENT	.2500E-01
P MAXIMUM VALUE	6.000
Q MAXIMUM VALUE	5.000
I.F. MINIMUM VALUE	-360.0
I.F. MAXIMUM VALUE	-330.0
P OF THE RECEIVER	1.000
Q OF THE RECEIVER	1.000

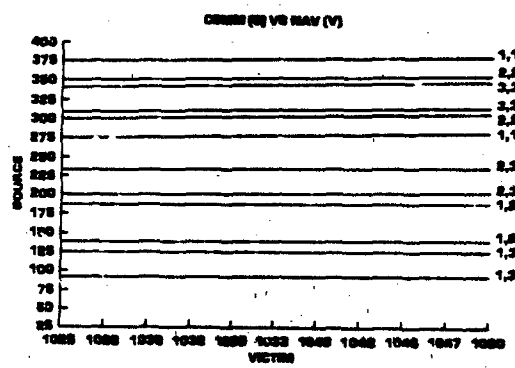
Figure 13. Receiver Spurious Response EMI Nomograph (Variable IF)



TEST DATA FOR GRAPH OF: COMM (S) VS NAV (V)

GRAPH TITLE	COMM (S) VS NAV (V)
TRANSMITTER MINIMUM VALUE	30.00
TRANSMITTER MAXIMUM VALUE	400.0
TRANSMITTER INCREMENT	.2500E-01
RECEIVER MINIMUM VALUE	1025.
RECEIVER MAXIMUM VALUE	1050.
RECEIVER INCREMENT	1.000
P MAXIMUM VALUE	9.000
Q MAXIMUM VALUE	5.000
I.F. MINIMUM VALUE	60.00
I.F. MAXIMUM VALUE	70.00
P OF THE RECEIVER	2.000
Q OF THE RECEIVER	1.000

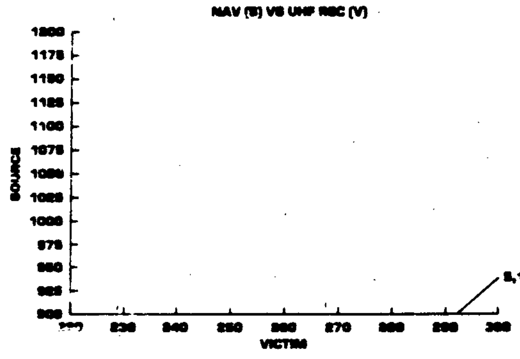
Figure 14. Dense Receiver Spurious Response EMI



TEST DATA FOR GRAPH OF: COMM (S) VS NAV (V)

GRAPH TITLE	COMM (S) VS NAV (V)
TRANSMITTER MINIMUM VALUE	30.00
TRANSMITTER MAXIMUM VALUE	400.0
TRANSMITTER INCREMENT	.2500E-01
RECEIVER MINIMUM VALUE	1025.
RECEIVER MAXIMUM VALUE	1050.
RECEIVER INCREMENT	1.000
P MAXIMUM VALUE	3.000
Q MAXIMUM VALUE	3.000
I.F. MINIMUM VALUE	[illegible]
I.F. MAXIMUM VALUE	[illegible]
P OF THE RECEIVER	3.000
Q OF THE RECEIVER	1.000

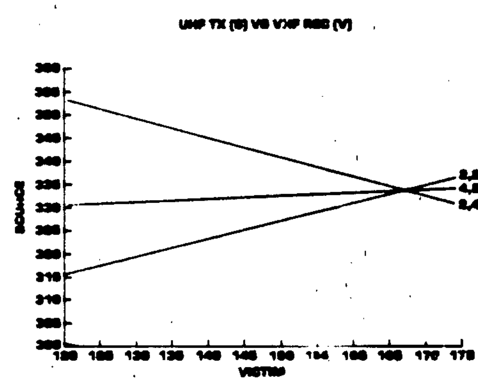
Figure 15. Reduced Density Spurious Response EMI Nomograph



TEST DATA FOR GRAPH OF: NAV (S) VS UHF REC (V)

GRAPH TITLE	NAV (S) VS UHF REC (V)
TRANSMITTER MINIMUM VALUE	900.0
TRANSMITTER MAXIMUM VALUE	1200.
TRANSMITTER INCREMENT	1.000
RECEIVER MINIMUM VALUE	225.0
RECEIVER MAXIMUM VALUE	300.0
RECEIVER INCREMENT	.2500E-01
P MAXIMUM VALUE	5.000
Q MAXIMUM VALUE	5.000
I.F. MINIMUM VALUE	140.0
I.F. MAXIMUM VALUE	140.0
P OF THE RECEIVER	1.000
Q OF THE RECEIVER	1.000

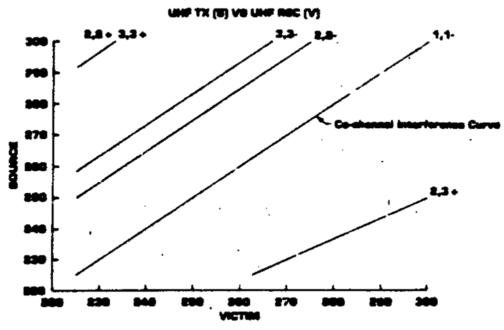
Figure 16. Insignificant Receiver Spurious Response EMI



TEST DATA FOR GRAPH OF: UHF TX (S) VS VHF REC (V)

GRAPH TITLE	UHF TX (S) VS UHF REC (V)
TRANSMITTER MINIMUM VALUE	300.0
TRANSMITTER MAXIMUM VALUE	360.0
TRANSMITTER INCREMENT	.2500E-01
RECEIVER MINIMUM VALUE	150.0
RECEIVER MAXIMUM VALUE	174.0
RECEIVER INCREMENT	.2500E-01
P MAXIMUM VALUE	5.000
Q MAXIMUM VALUE	5.000
I.F. MINIMUM VALUE	-301.0
I.F. MAXIMUM VALUE	-300.0
P OF THE RECEIVER	1.000
Q OF THE RECEIVER	1.000

Figure 17. Complex Receiver Spurious Response EMI



TEST DATA FOR GRAPH OF: UHF TX (S) VS UHF REC (V)

GRAPH TITLE	UHF TX (S) VS UHF REC (V)
TRANSMITTER MINIMUM VALUE	225.0
TRANSMITTER MAXIMUM VALUE	300.0
TRANSMITTER INCREMENT	.2500E-01
RECEIVER MINIMUM VALUE	225.0
RECEIVER MAXIMUM VALUE	300.0
RECEIVER INCREMENT	.2500E-01
P MAXIMUM VALUE	3.000
Q MAXIMUM VALUE	3.000
I.F. MINIMUM VALUE	-86.00
I.F. MAXIMUM VALUE	-86.00
P OF THE RECEIVER	1.000
Q OF THE RECEIVER	1.000

Figure 18. Co-channel Interference Curve

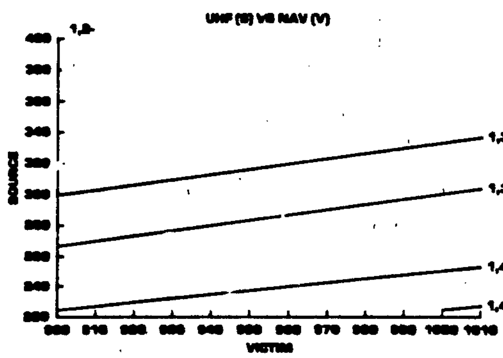


Figure 19. Harmonic Response EMI

After viewing the nomograph, the next step is to utilize the program's other features. The feature of plotting test data has application in the areas of reviewing proposed EMI/EMC test frequency selection plans and reporting of test results.

The NAVAIRTESTCEN EMC section's role as the center for Navy aircraft EMC testing requires the frequent reviewing of test plans proposed by airframe/avionics integrators for thoroughness. The EMC test plans usually contain an extensive EMC test frequency selection plan. These frequency selection plans can be reviewed rapidly for receiver spurious response EMI test thoroughness by the use of the SPRIG program. After setting up the nomograph for the proposed source and victim equipment, the test engineer enters the appropriate test frequencies from the frequency selection plan. The test frequencies will be plotted on the nomograph revealing whether the test frequencies are accurate (if they coincide with a curve) and sufficient in number to validate all receiver spurious respons. EMI possible (if a curve is not plotted with test frequencies). When there are areas where improvements are required, then the test engineer may use other features of the program to recommend additional test frequencies to the frequency selection plan.

The application of the feature to plot test data for test reports could result in a nomograph as shown in figure 20. The fictional test results on the graph indicate which curves are valid receiver spurious response EMI conditions which should be avoided in actual use. The field operators of the two equipment can avoid the receiver spurious response EMI by selecting a frequency pair from the nomograph which will not coincide with curves plotted with test data indicating known receiver spurious response EMI of the equipment.

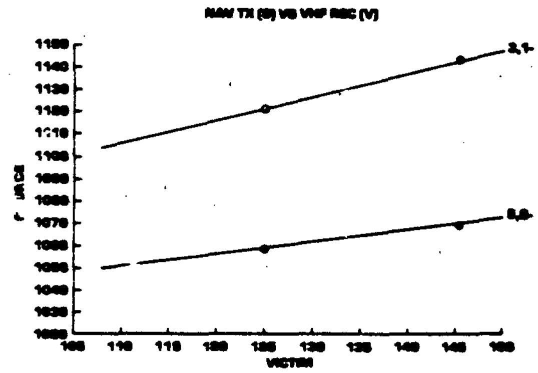


Figure 20. Receiver Spurious Response EMI Nomograph with Test Data

The utilization of the prediction capability of SPRIG comes from the two features of reading victim and source test frequencies from the nomograph and prediction of source frequencies based on a selected victim frequency. For example, using the nomograph of figure 17, a test engineer would want to evaluate the complex receiver spurious response EMI shown. The first step would be to position the computer program's graphic cursor over the intersection of the curves and obtain a victim (and source) frequency where this EMI could occur (figure 21). Then using the victim prediction feature, the program will calculate all possible receiver spurious response EMI for the victim frequency (figure 22). Both features for prediction provide actual values and proposed test frequencies based on channelization of the victim and source equipment.

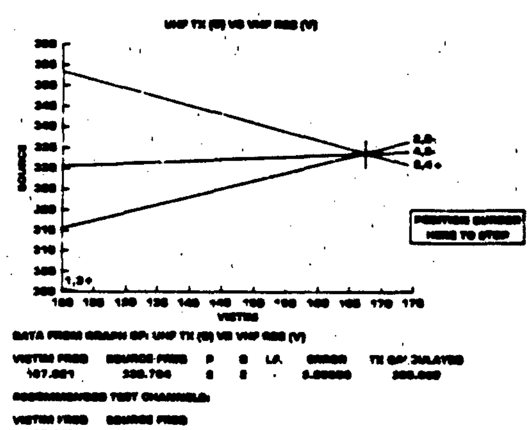


Figure 21. Read Data from Receiver Spurious Response EMI Display and Prediction Output

VICTIM PREDICTION

VICTIM FREQ	SOURCE FREQ	P	Q	I.F.	SOURCE CHANNEL
167.000	338.000	2	2	-	338.000
167.000	341.500	2	4	+	341.500
167.000	348.000	4	5	-	348.000

Figure 22. Victim Prediction

Summary

The SPRIG program provides an effective tool to analyze and predict receiver spurious response EMI. The nomograph presentation can be rapidly drawn, using a minimum amount of data. The resulting nomograph characterizes receiver spurious response of numerous frequency combinations on a single display. The algorithms used to implement the superheterodyne mathematical models in the computer program should enable other test engineers to develop similar programs to implement and utilize nomographs in their receiver spurious response EMI analysis and prediction programs. The application of the nomograph to analysis and prediction of receiver spurious response EMI enables new engineering techniques for verification of test frequency plans, interpretation of test data, portraying receiver spurious responses, and predicting of receiver spurious response. The application of receiver spurious response nomographs has allowed optimum, yet comprehensive, verification of the EMC design through testing at NAVAIRTESTCEN.

Reference

1. NAVAIR 5335, Naval Air Systems Command EMC Manual, of May 1972.

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