

# Inductive Interference Measurement Using the Wilcom T132B Spectrum Analyzer

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# 1. General

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- 1.1 Purpose** This practice provides information on the uses and applications of the Wilcom T132B Spectrum Analyzer for:
- Inductive interference.
  - Noise investigations.
- 1.2 Filing Instructions** Remove and discard Issue 1, and file this issue in its place in your GTE Telephone Operations practices set.
- 1.3 Reason for Reissuing** This practice has been reissued to incorporate multiple changes in the content. Read this entire practice to ensure your familiarity with the new information.
- 1.4 Supersedures** This practice supersedes:
- All local practices, policies, procedures, general instructions, letters, and memoranda which address this subject.
  - Any document which provides information contrary to the information contained in this practice.
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## 2. Overview

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### 2.1 Scope

This practice is limited to the uses and application of the exploring (search) coil. Uses of a probe wire are not included.

### 2.2 References

Refer to the following GTE Telephone Operations Practices for additional information:

- 109-I 10-006, Data Sheet Wilcom T132B Spectrum Analyzer and Noise Measuring Set.
- 887-800-041, Inductive Coordination Probe Wire Method.
- 887-800-042, Inductive Coordination Probe Wire Analysis.
- 887-800-050, Harmonic Suppressor Reactors.
- GTE Noise Reduction Handbook.
- PSB 4939 Ordering Information.

### 2.3 Acronyms Chart

The following chart defines acronyms and terms used in this practice.

Acronym	Definition
AFC	Automatic Frequency Control
Ng	Noise to Ground
Nm	Noise Metallic
NMS	Noise Measuring Set
RMS	Root-Mean-Square
RSS	Root-Sum-Square
SCR	Silicon Controlled Rectifier
TIF	Telephone Interfering Factor
Wf	Weighting Factor

### 2.4 Forms

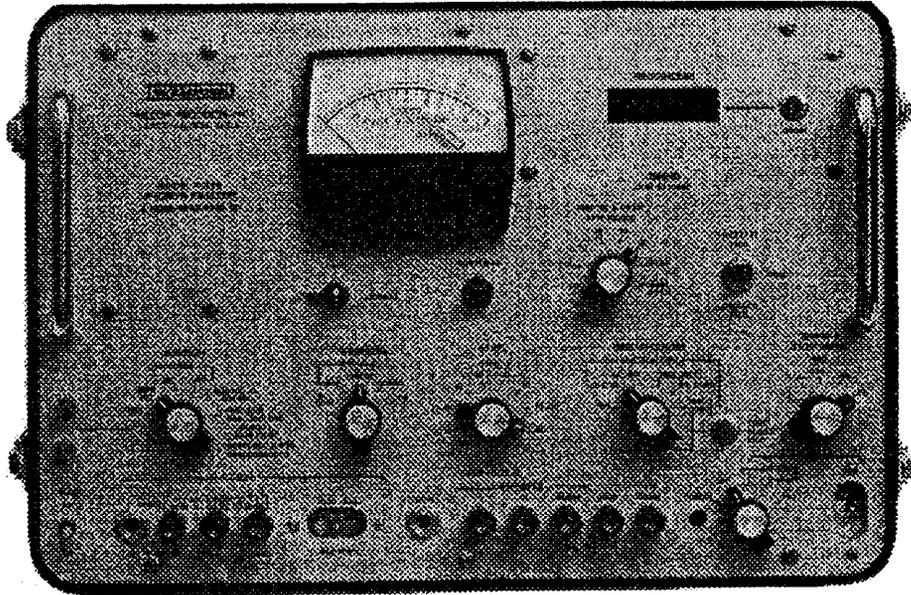
Form 90004692, Spectrum Analysis Data Form (see Exhibit 4), is available through the local stationery storerooms.

## 3. Description, Features, and Uses

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### 3.1 Description

The T132B set combines the functions of a Spectrum Analyzer and a Noise Measuring Set (NMS). The following illustration of the Wilcom T132B Spectrum Analyzer presents the front view of the T132B showing all operating controls, switches, and connectors.



The T132B offers the following general features:

- Operates from either internal batteries or AC line power (1  $\phi$ , 60 Hz).
- Frequency range is from 20 Hz to 50 kHz. Measurement level is from -5 to 100 dBm (-95 to + 10 dBm).
- All inputs are balanced and are DC blocked.
- Five settings on the weighting switch (20/F, 3 kHz, 50 kHz, C-msg, TIF).
- Function switch provides for five different input arrangements and impedances.
- Signal output provided for X-Y plotters, recorders, and oscilloscopes.

### 3.2 Spectrum Analyzer Features

When operated as a spectrum analyzer, the Spectrum T132B offers the following features:

- Five-digit numerical display of the desired frequency.
- Full level for signals within + /- 5 Hz of tuned frequency.
- 60 dB attenuation of signals differing by more than 50 Hz of tuned frequency.
- Manual tuning of frequency via lever switch.
- Automatic Frequency Control (frequency locks to an incoming signal).
- Frequency lock to a remembered value.
- Single and repeat frequency sweep capability.
- User-selected tuning-and-sweep rates.

### 3. Description, Features, and Uses, continued

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#### 3.3 Noise Measuring Set Features

When operated as an NMS, the T132B offers the following features:

- Quasi-Root-Mean-Square (RMS) response characteristic suited for broad band measurements.
- Automatic disabling of the frequency selective capability.

**NOTE: Refer to the Manufacturer's Instruction Manual for additional information on features and specifications.**

#### 3.4 General Uses

The T132B Spectrum Analyzer and NMS are used to analyze the harmonic content of the electric power system.

The **T132B** can be used:

- Directly on cable pairs.
- With an exploring (search) coil, such as the CCS 105.
- With a probe wire (100 feet long).

#### 3.5 CCS105 Description

The CCS105 is an exploring coil designed to be used with the T132B Spectrum Analyzer. The CCS105 has the following specifications:

Item	Specifications
Frequency Range	20 Hz to 3500 Hz
Frequency Response	+/- 1 dB 20 Hz - 2 kHz +/- 3 dB 2 kHz - 3.5 kHz <b>NOTE: With a load impedance greater than 50,000 ohms.</b>
Number of Turns	850
Effective Area	0.79 sq ft (0.735 m <sup>2</sup> )
Self Inductance	500 mH (approx.)
Resistance	300 ohms (approx.)
Weight	2.2 lbs (1 .0 kg)
Dimensions L	14-1/8" (360 mm)
H	9-7/16" (240 mm)
D	13/16" (20 mm)

## 4. Theoretical Background Information

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### 4.1 Introduction

The power influence measured on a cable pair is usually caused by the cable conductors being exposed to the magnetic field produced by the current flowing in the power line and returning through earth.

### 4.2 Power Influence

The magnitude of the power influence is a function of the magnitude of the power line current and its wave shape or harmonic content. The greater the power line current returning through earth, the higher the power influence.

Power influence is also greater for the higher harmonics of the power line current because:

- Coupling between power line and telephone cable tends to be frequency proportional.
- Power influence in telephone circuits is measured with C-Message weighting to show the actual impairment and annoyance potential of each frequency component. The power frequency harmonics normally fall in a much more sensitive portion of the C-Message weighting curve than does the fundamental.

### 4.3 Return Currents

The power line current that produces the magnetic field which most seriously affects the telephone cable is the unbalance current, which is forced to return to the power substation through a ground path, far enough away to provide little canceling effect. This is earth return current.

### 4.4 Balanced Phase Currents

The coupling to the telephone cable will tend to cancel out and cause little trouble if the phase currents in the power line are well balanced, or if the unbalance is carried on a neutral conductor close to the phase conductors.

### 4.5 Unbalanced Phase Currents

Unbalances in the power system can cause earth return currents, which can introduce noise or voltage on the telephone facility.

About half of the unbalance current will flow in the power neutral, telephone strand, and cable shield. The other half flows through earth.

### 4.6 Measuring Earth Return Currents

One way to measure earth return current is to have the power company measure each phase wire and neutral at a particular location with a clamp-on ammeter and compute the ground return current. This method is accurate, but it is time consuming, especially when several locations need to be measured.

The earth return current along a power line is usually measured after it has been determined that the circuit noise in the telephone facilities cannot be reduced to an acceptable level through further work on the telephone plant.

**NOTE: Power system earth return currents must be determined by the telephone company engineers prior to contacting the power company.**

## 5. Harmonics

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### 5.1 Introduction

Harmonics are the sinusoidal components of a periodic wave having an integral multiple of the fundamental frequency. For example, in a 60 Hz system, 540 Hz would be the 9th harmonic ( $540/60 = 9$ ).

The two main groupings of harmonics are:

- ODD The integral multiple is an odd number; e.g., 180 Hz ( $180/60 = 3$ ).
- EVEN The integral multiple is an even number; e.g., 240 Hz ( $240/60 = 4$ ).

Analysis of the power system harmonic earth return currents will often identify problems in power systems that lead to economic penalties to the power company.

The information gathered from harmonic analysis tests will facilitate more successful inductive coordination action with power company engineers.

#### **5.1.1 Odd Harmonics**

Odd harmonics are usually predominant in power systems, especially the odd triple harmonic where the integral number is a multiple of 3 (e.g.,  $540/60 = 9$  and  $9/3 = 3$ ).

#### **5.1.2 Even Harmonics**

Even harmonics:

- Are not usually present in power systems.
- Can be found with rectifying or inverting loads.

**NOTE: Random harmonics, usually associated with cycloconverters, are also possible.**

### 5.2 Methods for Harmonic Analysis

There are two methods by which GTE personnel can measure power line earth return currents without the assistance of power company personnel and without direct contact with power facilities. The two methods involve the use of:

- An exploring (search) coil such as the Wilcom Model CCS105.
- OR
- A 100-foot probe wire.

#### **5.2.1 Exploring Coil**

When an exploring coil is placed near a power line, the magnetic field produced by the power line is measured, and qualitative information regarding the influence of the line can be obtained.

Proper orientation of the exploring coil under the power line makes it possible to determine the relative magnitude of the balanced or residual components of the influence.

**NOTE: The exploring coil method is advantageous because it does not require a conductive path to earth, as does the probe wire; therefore, less time is usually required to setup and complete the measurements at a given location.**

## 5. Harmonics, continued

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### 5.2 Methods for Harmonic Analysis, continued

#### 5.2.2 Probe Wire

The probe wire method is the best method for obtaining a quantitative indication of the coupling between the telephone cable pairs and the power line conductors.

The length and location of the probe wire are carefully controlled to ensure obtaining accurate information about the magnitude and frequency composition of the interfering field.

The probe wire may be subjected to ground voltages resulting from other sources at the fundamental and lower harmonic frequencies. These voltages may introduce errors in the results.

**NOTE: For more detailed information on the probe wire method, refer to GTE Telephone Operations Practices:**

- 887-800-041, Inductive Coordination Probe Wire Method.
- 887-800-042, Inductive Coordination Probe Wire Analysis.

### 5.3 Identifying Problems

The power line problem areas that can be identified with the probe wire or exploring coil methods are:

- Unbalanced loads in a three-phase power system.
- Excessive exposure length to a single-phase power system.
- Problems with the neutral conductor (open, defective, or too small).
- Open capacitors, malfunctioning capacitors, or defective capacitor cans.
- Open capacitor fuses.
- Malfunctioning capacitor banks - change in capacitance.
- Circuit resonance.
- Power transformer problems.
- Harmonics from generators or motors.
- Harmonics from SCF? control devices.
- Harmonics from rectifiers AC and DC.
- Shielding problems (open sheath) in the telephone cable.

**NOTE: Refer to Section 10.1, Reference Table, for more specific information about additional possible causes.**

## 6. Harmonic Cable Pair Analysis

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### 6.1 Introduction

This section deals with techniques for measuring and analyzing the harmonic content of the Noise to Ground (Ng) or power influence on a cable pair.

These techniques are applicable when:

- The methods presented in the GTE Noise Reduction Handbook have been followed and have failed to solve the problem.
- Conventional isolation methods and shield continuity testing (with the T136BGM, T137B, T139, T304 etc.) have:
  - Failed to pinpoint the causes.
  - Shown inconclusive results.

Use a cable pair harmonic analysis to obtain information that will help determine the direction for subsequent investigations.

Measuring the induced longitudinal voltage to ground in a telephone cable pair at the power line fundamental and harmonic frequencies can provide valuable information relative to the operation of the power system.

Studying recorded data from a harmonic analysis on a telephone cable pair provides information that will help identify and locate power system problems.

Adequate information is obtained by using this method on cables that parallel power lines, even though the magnitude of the earth return currents cannot be accurately determined through the measurement of the longitudinally induced harmonic voltage.

### 6.2 Data Gathering

Data for the analysis is obtained by measuring and recording the Ng at fundamental and harmonic frequencies on a noisy cable pair. Conduct tests on an idle pair if available.

For most accurate results, measure all harmonic frequencies of the power system fundamental frequency from the first (60 Hz) to the forty-seventh (2820 Hz), and record information on a data sheet.

A sample data form is shown in Exhibit 1, Harmonic Analysis Data Sheet. This form provides for recording power influence level (Ng + 40) in dBm, either with C-Message or 3 kHz weighting, for each harmonic frequency.

Column 3 lists the average noise levels obtained in statistical studies. The actual measurements that fall below the averages shown on Column 3 are disregarded during the analysis of the data.

## 6. Harmonic Cable Pair Analysis, continued

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### 6.3 Composite Measurements

Take composite noise measurements according to the instructions in the following chart.

---

Harmonic Settings	Measurements
3 kHz	<ul style="list-style-type: none"><li>• Power Influence (PI = Ng + 40)</li><li>• Circuit Noise (Nm)</li><li>• Balance (Balance = PI - Nm)</li></ul>
C-Message	<ul style="list-style-type: none"><li>• Power Influence (PI = Ng + 40)</li><li>• Circuit Noise (Nm)</li><li>• Balance (Balance = PI - Nm)</li></ul>

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**NOTE:** If during the actual test, a frequency other than the ones listed on the form is found, record it on the data sheet.

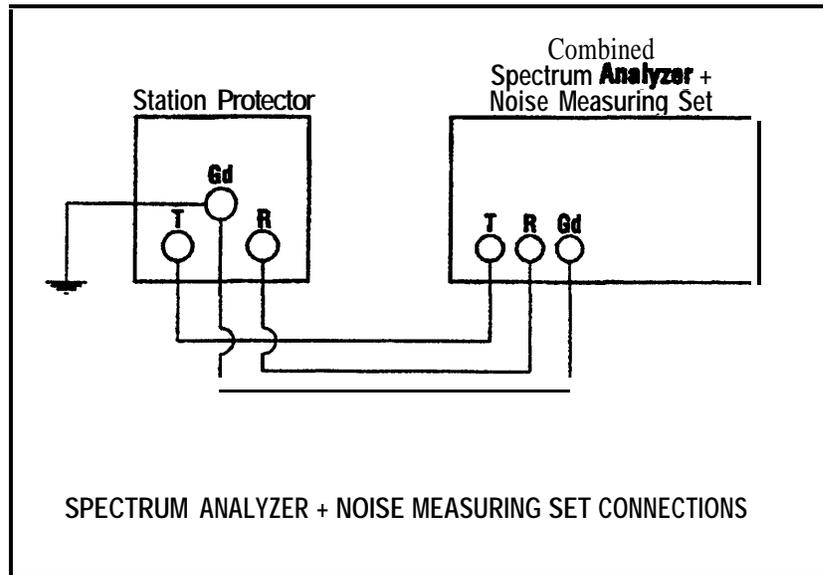
## 6. Harmonic Cable Pair Analysis, continued

### 6.4 Performing the Test

To perform the test on working cable pairs, follow the steps in the chart below.

#### Step Testing Working Cable Pairs

- 1 Perform the tests using the setup shown in the illustration below from a location close to the end of the cable and as near to the station protector as possible in order to:
  - Use a good, low resistance ground.
  - Ensure that as much of the facility as possible is tested.



- 2 Dial the office quiet termination.
- 3 Switch the holding coil to ON and make the measurements.

To perform the test on idle cable pairs, follow the steps in the chart below.

#### Step Testing Idle Cable Pairs

- 1 Perform the tests using the setup shown in the illustration above, from either end.
- 2 Connect the T132B test set to a good, low resistance ground (either a ground rod at a field location or the CO ground).
- 3 Short and ground the cable pair at the opposite end.

## 7. Harmonic Cable Pair Analysis Measurements

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### 7.1 T132B Settings

For harmonic analysis of a cable pair, set the T132B according to the charts below:

**NOTE:** Only one of the harmonic settings is needed (either 3 kHz or C-Message).

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Test Using 3 kHz	Set the T132B as Follows
Noise to Ground (Ng) - 3 kHz	<ul style="list-style-type: none"><li>• Function switch set to: NG</li><li>• Weighting switch: 3 kHz</li><li>• Operating Mode: NMS</li></ul>
Circuit Noise (Nm) - 3 kHz	<ul style="list-style-type: none"><li>• Function switch set to: 900</li><li>• Weighting switch: 3 kHz</li><li>• Operating Mode: NMS</li></ul>
Harmonics - 3 kHz	<ul style="list-style-type: none"><li>• Function switch set to: NG</li><li>• Weighting switch: 3 kHz</li><li>• Operating Mode: AFC ON</li></ul> <p><b>NOTE:</b> Set the tuning-and-sweep rate and range switches as needed.</p>

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Test Using C-Message	Set the T132B as Follows
Noise to Ground (Ng) - C-Message	<ul style="list-style-type: none"><li>• Function switch set to: NG</li><li>• Weighting switch: C-MSG</li><li>• Operating Mode: NMS</li></ul>
Circuit Noise (Nm) - C-Message	<ul style="list-style-type: none"><li>• Function switch set to: 900</li><li>• Weighting switch: C-MSG</li><li>• Operating Mode: NMS</li></ul>
Harmonics - C-Message	<ul style="list-style-type: none"><li>• Function switch set to: NG</li><li>• Weighting switch: C-MSG</li><li>• Operating Mode: AFC ON</li></ul> <p><b>NOTE:</b> Set the tuning-and-sweep rate and range switches as needed.</p>

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# 7. Harmonic Cable Pair Analysis Measurements, continued

## 7.1 T132B Settings, continued

Follow the steps in the chart below for harmonic analysis and testing:

Step	Performing Harmonic Analysis and Testing						
1	Set the: <ul style="list-style-type: none"> <li>• Operating Mode switch to AFC OFF.</li> <li>• Tuning-and-Sweep Rate to 10 or 20.</li> <li>• Tuning-and-Sweep Range to 4.</li> <li>• Level switch to 20.</li> </ul>						
2	Push the Frequency Hz ON-OFF button switch in the upper right corner. A readout should appear in the small window to the left.						
3	Using the Increase Frequency/Decrease Frequency lever switch located to the right of the meter, tune the T132B to 60 Hz. Turn the switch toward: <ul style="list-style-type: none"> <li>• Increase Frequency to tune upward in frequency.</li> <li>• Decrease Frequency to tune downward in frequency.</li> </ul>						
4	When 60 appears in the-digital readout, turn the operating mode switch to AFC ON. If necessary, adjust the Level switch to a scale for maximum deflection of the needle.						
5	Read the measurement, add 40, and record it on the data sheet. (Use either Exhibit 1, Harmonic Analysis Data Sheet, or Exhibit 4, Spectrum Analysis Data Form.)						
6	Set the Operating Mode switch to AFC OFF, and use the Increase Frequency/Decrease Frequency to tune the T132B to the next frequency of interest.  <b>NOTE: Obtain composite (overall) readings immediately before and after taking Individual harmonic readings.</b>						
	<table border="1"> <thead> <tr> <th>If...</th> <th>Then...</th> </tr> </thead> <tbody> <tr> <td>The NMS readings are the same or relatively close</td> <td>The conditions did not change during the spectrum analysis, and the data obtained is useable.</td> </tr> <tr> <td>The difference in before and after measurements is significant</td> <td>Repeat the spectrum analysis.</td> </tr> </tbody> </table>	If...	Then...	The NMS readings are the same or relatively close	The conditions did not change during the spectrum analysis, and the data obtained is useable.	The difference in before and after measurements is significant	Repeat the spectrum analysis.
If...	Then...						
The NMS readings are the same or relatively close	The conditions did not change during the spectrum analysis, and the data obtained is useable.						
The difference in before and after measurements is significant	Repeat the spectrum analysis.						

## 7. Harmonic Cable Pair Analysis Measurements, continued

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### 7.2 Analyzing the Data

Analyzing the data involves comparing the values obtained for each harmonic against the statistical studies (Column 3 of the data form shown in Exhibit 1, Harmonic Analysis Data Sheet).

A graph has been constructed (see Exhibit 2, Voltage-to-Ground) showing the average or mean ( $\mu$ ) level as well as the upper standard deviation ( $\sigma$ ).

Plot all the measurements from the harmonic analysis data sheet to the graph. Include all harmonics frequencies with measurements exceeding the mean values listed on the data sheet.

### 7.3 Patterns

Each of the problem areas listed in Section 5.3, Identifying Problems, has its own pattern of harmonics that will exceed the ( $\mu + \sigma$ ) point. Analysis is somewhat complicated when two or more problems exist along a single route.

When the results of power influence measurements are equal to or less than the plotted ( $\mu + \sigma$ ) values, and the telephone facility has a good balance (60 dB or better), there should not be a noise problem.

A measured value above the standard deviation level is considered to be excessive. Measured values falling between the standard deviation and the mean levels are marginal. All measured values below the mean level are acceptable.

### 7.4 Shielding Problems

Cable shielding problems will usually cause excessive readings in the range of 420-1860 Hz.

Repeat tests outlined in Section 7.1, T132B Settings, after all corrective action has been taken.

**NOTE: Correct all cable shielding problems before contacting the power company.**

## 8. CCS105 Exploring Coil Measurements

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### 8.1 Usage

The exploring (search) coil is used with a spectrum analyzer to:

- Quickly locate some types of power line problems.
- Measure either the overall or the individual frequency earth return current of a power line.
- Locate or identify various power system components that might be contributing to a telephone system noise problem.
- Measure earth return currents of a power line:
  - At any harmonic frequency.
  - Anywhere along its entire length.
  - Without the use of ground rods.
  - Without direct contact with the power line.

**NOTE: This method provides only an approximation of the actual current magnitude. The probe wire method is most accurate.**

#### **8.1.1 Diagnostic Technique**

Exploring coil measurements are useful as a diagnostic technique. Quantitative measurements are usually not possible due to the sensitivity to secondary induction from parasitic conductors.

Because of its compact size and portability, the exploring coil is very useful in:

- Determining levels of unusually high influence.
- Estimating relative levels where probe wire measurements are:
  - Not possible.
  - Difficult to obtain.

#### **8.1.2 Exploring Coil Method**

Use this method as the initial step in a specialized noise investigation or as an operation subsequent to the harmonic analysis of a cable pair.

#### **8.1.3 Preliminary Tests**

The preliminary step involves the study of the entire power line with the exploring coil by pointing the hand-held coil toward the power line from a vehicle while traveling along the power line.

Monitoring the harmonic level can indicate where capacitor banks might be providing a low impedance path to ground for harmonic currents, the location of overexcited transformers, etc.

## 8. CCSI 05 Exploring Coil Measurements, continued

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### 8.1 Usage, continued

#### 8.1.4 Preliminary Procedures

Connect the exploring coil to the input of the spectrum analyzer and follow the steps in the following chart.

---

Step	Preliminary Procedures
1	Select the harmonic frequency of interest. Use the AFC setting to compensate for frequency drift. <b>NOTE: Composite NMS or 540 Hz most often work the best.</b>
2	A. Hold the coil outside the vehicle and point it directly at the power wires. B. Orient the coil to obtain a maximum reading.
3	<b>CAUTION: Observe ALL safety measures. This operation requires two people (a driver and a test set operator).</b> A. Move along the power line in the vehicle observing the magnitude of the harmonic frequency. B. Reorient the coil when the location of the power line changes in relation to the road.
4	Study the entire power fine, although it might extend beyond the telephone facilities in question.
5	A. Make note of locations where there is a significant change in the magnitude of the harmonic frequency. B. Investigate these locations to determine the causes of the level changes. <b>NOTE: If one of the above locations is at a lateral or tap break-off point, investigate the lateral lead.</b>

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### 8.2 Precise Measurements

When the preliminary information is obtained, complete more precise measurements to determine problem location and severity for:

- Probe wire analysis. (Refer to GTE Telephone Operations Practice 887-800-041.)
- Exploring coil tests (Refer to Section 8.5, T132B Settings/Test Procedures.)

### 8.3 Additional Measurements

Take additional measurements two or three spans on either side of the location where the significant changes were recorded.

Perform a harmonic analysis. (Refer to Section 8.5.)

### 8.4 Selecting Test Points

When selecting the actual test points for an in-depth study, avoid:

- Power line spans that include secondary distribution leads. The secondary distribution wires will alter the magnetic field and can cause significant error in earth return current measurements.
- Power fine discontinuities such as bridge taps, dead-ends, corners, and distribution transformers. These discontinuities also distort the magnetic fields.
- Buried metallic pipelines, cables, or other metallic objects.
- Metal fences beneath, near, or parallel to the power line. Metal fences cause the magnetic fields to be stronger at the earth's surface.

## 8. CCS105 Exploring Coil Measurements, continued

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### 8.5

#### T132B Settings/ Test Procedures

When using the exploring coil method of T132B settings harmonic analysis, set the T132B:

- Function switch set to: BRDG 600.
- Weighting switch: C MSG.
- Operating Mode: NMS or AFC ON. (See Section 8.2.)

Use the instructions in the chart below to test with the T132B.

Step	Testing with the T132B
1	Select a point close to the center of the span.
2	Determine the distance (within two feet) from the center of the exploring coil to: <ul style="list-style-type: none"><li>• The neutral conductor.</li><li>• Each of the phase conductors.</li></ul>
3	Calculate the average distance to the power conductors (H) from the center of the exploring coil. This distance is recorded on Line 4 of the data form. <b>NOTE: Use the data sheet (see Exhibit 3, Power System Current Wave Form - Harmonic Analysis - Data Sheet - C Sheet) to record all the measured data. These forms are available from Wilcom as the T132B-Pad C.</b>
4	Enter the Correction Factor (CF) on Line 5 of the data sheet. The CF is calculated from $CF = 20 \log H - 6.5$ where H = height of power line. <b>NOTE: The factors shown on the C sheet (see Exhibit 3) are applicable only to the CCS105 Exploring Coil. Other exploring coils may require different correction factors.</b>
5	Connect the exploring coil to the spectrum analyzer with a two-wire cord with dual banana plugs (or alligator clips) at each end.
6	Position the exploring coil directly under the power line with the long sides parallel to the power line and the short sides perpendicular to it.
7	Set the 5 as follows: <ul style="list-style-type: none"><li>• TIF Weighted - C-Message<ul style="list-style-type: none"><li>- Function switch to: BRDG 600</li><li>- Weighting switch: C-MSG</li><li>- Operating Mode: AFC ON</li></ul></li><li>• Unweighted - 20/F<ul style="list-style-type: none"><li>- Function switch to: BRDG 600</li><li>- Weighting switch: 20/F</li><li>- Operating Mode: AFC ON</li></ul></li></ul> <b>NOTE: DO NOT use the 3 kHz flat weighting, since it might be necessary to measure frequencies higher than 3 kHz.</b>

(continued)

## 8. CCS105 Exploring Coil Measurements, continued

### 8.5

#### T132B Settings/ Test Procedures, continued

Step	Testing Procedures						
8	<p>On the first measurement, rock the exploring coil slowly from side to side on the longitudinal axis to a position of maximum reading.</p> <p><b>NOTE:</b> If the exploring coil is at an angle to the power line, there is the possibility of a magnetic field from a buried metallic object influencing or changing the reading.</p>						
9	<p>Lift the exploring coil slowly in the plane of the maximum reading.</p> <p><b>NOTE:</b> An increase in the reading indicates that the coil is under the influence of the power line magnetic field and the data obtained should be reliable.</p> <table border="1"> <thead> <tr> <th>If...</th> <th>Then...</th> </tr> </thead> <tbody> <tr> <td>me measurement decreases</td> <td> <p>The coil is being influenced by the magnetic field of a buried or nearby metallic object, and the results will not be totally accurate.</p> <p>When these conditions exist, move the exploring coil approximately 30 feet or more from the power line, and repeat Steps 1-9.</p> </td> </tr> <tr> <td>The influences persist</td> <td>Find a new test location.</td> </tr> </tbody> </table>	If...	Then...	me measurement decreases	<p>The coil is being influenced by the magnetic field of a buried or nearby metallic object, and the results will not be totally accurate.</p> <p>When these conditions exist, move the exploring coil approximately 30 feet or more from the power line, and repeat Steps 1-9.</p>	The influences persist	Find a new test location.
If...	Then...						
me measurement decreases	<p>The coil is being influenced by the magnetic field of a buried or nearby metallic object, and the results will not be totally accurate.</p> <p>When these conditions exist, move the exploring coil approximately 30 feet or more from the power line, and repeat Steps 1-9.</p>						
The influences persist	Find a new test location.						
10	Set the spectrum analyzer to 60 Hz, first using the C-Message weighting and then to the 20/F (or 50 kHz) weighting.						
11	Record each measurement obtained in the appropriate column on the data sheet.						
12	Repeat Steps 10 and 11 for each of the harmonics from 120 Hz through 2820 Hz.						
13	<p>Obtain the composite (overall) reading by setting the 11328 as:</p> <ul style="list-style-type: none"> <li>• TIF Weighted - C-Message <ul style="list-style-type: none"> <li>- Function switch to: BRDG 600</li> <li>- Weighting switch: C-MSG</li> <li>- Operating Mode: NMS</li> </ul> </li> <li>• Unweighted - 20/F <ul style="list-style-type: none"> <li>- Function switch to: BRDG 600</li> <li>- Weighting switch: 20/F</li> <li>- Operating Mode: NMS</li> </ul> </li> </ul>						
14	Record all the actual measurements in the appropriate columns on the data sheet.						
15	Proceed to the next location and repeat Steps 1 through 14 until all locations of interest have been tested.						

## 9. Description of the Data Sheet

---

### 9.1 Instructions

Use the data sheet (see Exhibit 3) to record all the measured data. This form is available from Wilcom as the T132B-Pad C. Other similar forms may be used to record the measured data. Instructions for the data sheet are described below.

Line	Description	Refer To/Enter
(4)	Power Line Height	See Section 8.5, T132B Settings/Test Procedures, Steps 1-2.
(5)	Correction Factor	See Section 8.5, Step 3.
(6)	20/F Composite Reading - NMS	See Section 8.5, Step 13.
(7)	Actual C-Message measurement in dB	See Section 8.5, Steps 1 O-1 2.
(8)		Column 7 + Correction Factor.
(9)	If Wf in weighted amps in dBA	See formula in Section 9.2, Computations
(10)		Actual 20/F measurement in dB.
(11)		Column 10 + Correction Factor - 40 dB.
(12)	If amps	See formula in Section 9.3, Formulas.
(13)		NOT USED
(14)		NOT USED

### 9.2 Computations

Use mathematical formulas to compute:

- Column 9. (See Section 9.3, Formulas.)
- Column 12. (See Section 9.3.)
- Column 9, Power Sum. (See Section 9.4, Root Sum Square.)
- Column 12, Power Sum. (See Section 9.4.)
- TIF Contribution. (See 9.6, Numerical TIF and 9.7, TIF RSS.)

### 9.3 Formulas

Column 9 is calculated using the following formula:

$$I^*T = \log^{-1} \left\{ \frac{If^*Wf}{20} \right\}$$

Where If\*Wf is the quantity in Column 8.

Column 12 is calculated using the following formula:

$$I = \log^{-1} \left\{ \frac{If}{20} \right\}$$

## 9. Description of the Data Sheet, continued

---

### 9.4 Root Sum Square (RSS)

Once I\*T (Column 9) and I (Column 12) have been calculated for each frequency, the root sum square (RSS) for each is calculated using the following formulas:

- For I\*T (Column 9):  
$$RSS = (\text{Sum } \{I \cdot T\}^2)^{1/2}$$
- For I (Column 12):  
$$RSS = \{\text{Sum } \{I^2\}\}^{1/2}$$

The calculated RSS values should be nearly equal to the composite (overall) measured values. A large discrepancy indicates that:

- An error was made in the calculations or in the individual single frequency measurements.

OR

- One or more single frequencies were omitted.

### 9.5 Telephone Interfering Factor (TIF)

The Telephone Interfering Factor (TIF) is an index to the interfering effect of power system currents or voltages on nearby telephone circuits.

The TIF of a voltage or current wave form in an electric power supply circuit is the ratio of the square root of the sum of the squares (RSS) of the weighted RMS values of all the sine wave components to the unweighted RMS value of the entire wave. TIF is a dimensionless quantity indicative of wave form and not of amplitude.

### 9.6 Numerical TIF

Calculate the numerical TIF (Column 14), if needed, as follows:

$$TIF = \log-1 \left\{ \frac{Tf}{20} \right\}$$

Where Tf = Column 7 - Line 6 + 40 dB

### 9.7 TIF RSS

Once TIF (Column 14) has been calculated for each frequency, the root sum square (RSS) is calculated using the following formula:

$$RSS = (\text{Sum } \{TIF\}^2)^{1/2}$$

## 9. Description of the Data Sheet, continued

---

### 9.8 Data Analysis

Generally, when the overall earth return current (Column 12) approaches or exceeds 20 amperes, there is a possibility of a fundamental frequency voltage problem.

---

Item	Problem Description
Individual Currents	Individual currents in the range of 0.1 to 1.0 amperes suggest problems. The lower harmonics (180, 300, 420 Hz) should reach the upper level of the range before being suspected. For 540 Hz currents, as low as 0.1 amp suggests a problem area, especially on long exposures.
Individual I*T	As a general rule, when the I*T value at an individual frequency exceeds 500, there is a possibility of noise in the telephone facilities that parallel that power line. The possibility of noise is less (although not impossible) for values under 500.
Composite I*T	A composite I *T value of 1000 or more indicates an area of an excessive influence level.

---

### 9.9 Nomographs

Nomograph equipment is accompanied by an instruction manual containing a series of nomographs to simplify the mathematical calculations.

**DO NOT** use the nomographs, because:

- A great deal of accuracy is lost.
- Extreme care has to be exercised to use the correct one.
- Power sums are still required.
- Additional steps are necessary.

### 9.10 Computer Programs

Computer programs are now available to make all the necessary calculations. Programmable calculators may be used when computers are not available.

### 9.11 Spectrum Analysis Data Form

Use Form 90004692, Spectrum Analysis Data Form, shown in Exhibit 4, for recording the data obtained during the analysis.

## 10. Determining Possible Causes

---

### 10.1

#### Reference Table

After analyzing the data and identifying the harmonic frequencies exceeding the threshold, use the following table to determine the possible causes of interference.

<b>Interfering Frequency</b>	<b>Probable Cause</b>
60	<ul style="list-style-type: none"><li>• Poorly balanced three-phase power system.</li><li>• Extended exposure to single-phase power circuits.</li><li>• Three-phase capacitor bank problems.</li></ul>
180	<ul style="list-style-type: none"><li>• Unbalanced three-phase power system.</li><li>• Over excitation of power transformers.</li><li>• Grounded three-phase power transformer with no tertiary windings.</li></ul>
300	<ul style="list-style-type: none"><li>• Damaged capacitor bank.</li><li>• Over excitation of power transformers.</li><li>• Silicon Controlled Rectifier (SCR) devices.</li></ul>
420	<ul style="list-style-type: none"><li>• Over excitation of power transformers.</li><li>• Damaged capacitor bank.</li></ul>
540	<ul style="list-style-type: none"><li>• Over excitation of power transformers.</li><li>• Grounded three-phase power transformer with no tertiary windings.</li></ul>
660	<ul style="list-style-type: none"><li>• Damaged capacitor bank.</li><li>• SCR devices.</li><li>• 6-pulse rectifiers.</li></ul>
780	<ul style="list-style-type: none"><li>• Defective transformer.</li><li>• 6-pulse rectifiers.</li></ul>
900	<ul style="list-style-type: none"><li>• Sodium vapor lamps.</li><li>• Grounded three-phase power transformer with no tertiary windings.</li></ul>
1020	Induction-type machines.
1140	<ul style="list-style-type: none"><li>• SCR devices.</li><li>• Gaseous discharge lighting.</li></ul>

(continued)

## 10. Determining Possible Causes, continued

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### 10.1 Reference Table, continued

Interfering Frequency	Probable Cause
1260	Gaseous discharge lighting.
1380	12-pulse rectifiers.
1500	<ul style="list-style-type: none"> <li>● 12-pulse rectifiers.</li> <li>● Gaseous discharge lighting.</li> </ul>

### 10.2 Additional Possible Causes

Additional possible causes include:

if...	Then the Possible Cause Is...
me controlling harmonics are one or two non-triples	A balanced synchronous adjacent generator or motor. Typical harmonics are 23rd, 25th, and odd 27th.
One or two odd adjacent non-triples are predominant, and the harmonic frequency is not an exact multiple of the fundamental	An induction machine. Thirteenth (13th) and 17th harmonics are typical for medium size machines. Larger DC machines will have higher order harmonics.
One or more odd triple harmonics are predominant	A directly connected, grounded neutral in a generator, motor, or large transformer circuit with inadequate delta compensating windings.
The 3rd, 5th, 7th, and 9th harmonics are the most predominant	An overexcited transformer.
me frequencies are falling in the $P_n + /- 1$ scheme	Rectifier problems tend to exhibit this scheme. For instance, a 6-pulse rectifier will have 5th, 7th, 11th, 13th, etc. predominant harmonics.

# Exhibits

## HARMONIC ANALYSIS DATA SHEET

AREA \_\_\_\_\_ DATE \_\_\_\_\_  
 EXCHANGE \_\_\_\_\_ TIME \_\_\_\_\_  
 ROUTE/CABLE#, \_\_\_\_\_ PAIR \_\_\_\_\_  
 TESTED BY \_\_\_\_\_

## OVERALL NOISE MEASUREMENT

POWER INFLUENCE <sup>3kHz.</sup> (Ng+40) \_\_\_\_\_ dBm  
 CIRCUIT NOISE (Nm) \_\_\_\_\_ dBm  
 BALANCE \_\_\_\_\_ dB

POWER INFLUENCE <sup>C-Msg.</sup> (Ng+40) \_\_\_\_\_ dBm  
 CIRCUIT NOISE (Nm) \_\_\_\_\_ dBm  
 BALANCE \_\_\_\_\_ dB

1. Freq. Hz	2. Level Ng+40 (dBmC)	3. Disregard if Levels Are Less Than (dBmC)
60		59.3
120		48.2
180		49.5
240		70.8
300		67.5
360		64.9
420		66.8
480		68.9
540		71.2
600		65.3
660		60.7
720		57.7
780		55.4
840		55.0
900		53.4
960		50.8
1020		49.0
1080		46.9
1140		44.9
1200		44.8
1260		43.6
1320		42.4
1380		42.3
1440		41.1
1500		41.0
1560		39.9
1620		39.9
1680		39.8
1740		39.8
1800		33.7
1860		37.7
1920		37.7
1980		36.7
2040		36.7
2100		35.7
2160		35.7
2220		35.7
2280		35.7
2340		35.7
2400		34.6
2460		34.6
2520		34.6
2580		34.5
2640		34.4
2700		34.3
2760		34.2
2820		34.1

1. Freq. Hz	2. pf Level (Ng+40) (dBm 3KHz)	3. Disregard if Levels Are Less Than (dBm 3KHz)
1	60	11.5
2	120	10.6
3	180	9.7
4	240	9.2
5	300	8.3
6	360	8.0
7	420	7.7
8	480	7.7
9	540	7.7
10	600	7.0
11	660	6.5
12	720	6.1
13	780	5.8
14	840	5.7
15	900	5.5
16	960	5.1
17	1020	4.8
18	1080	4.7
19	1140	4.6
20	1200	4.5
21	1260	4.4
22	1320	4.3
23	1380	4.3
24	1440	4.2
25	1500	4.2
26	1560	4.1
27	1620	4.1
28	1680	4.1
29	1740	4.1
30	1800	4.0
31	1860	3.9
32	1920	3.9
33	1980	3.8
34	2040	3.8
35	2100	3.7
36	2160	3.7
37	2220	3.7
38	2280	3.6
39	2340	3.5
40	2400	3.5
41	2460	3.4
42	2520	3.4
43	2580	3.4
44	2640	3.4
45	2700	3.4
46	2760	3.4
47	2820	3.4

Exhibit 1 - Harmonic Analysis Data Sheet

# Exhibits, continued

Area \_\_\_\_\_ Date \_\_\_\_\_  
 Exchange \_\_\_\_\_ Time \_\_\_\_\_  
 Route/Cable # \_\_\_\_\_ Pair \_\_\_\_\_  
 Tested by \_\_\_\_\_

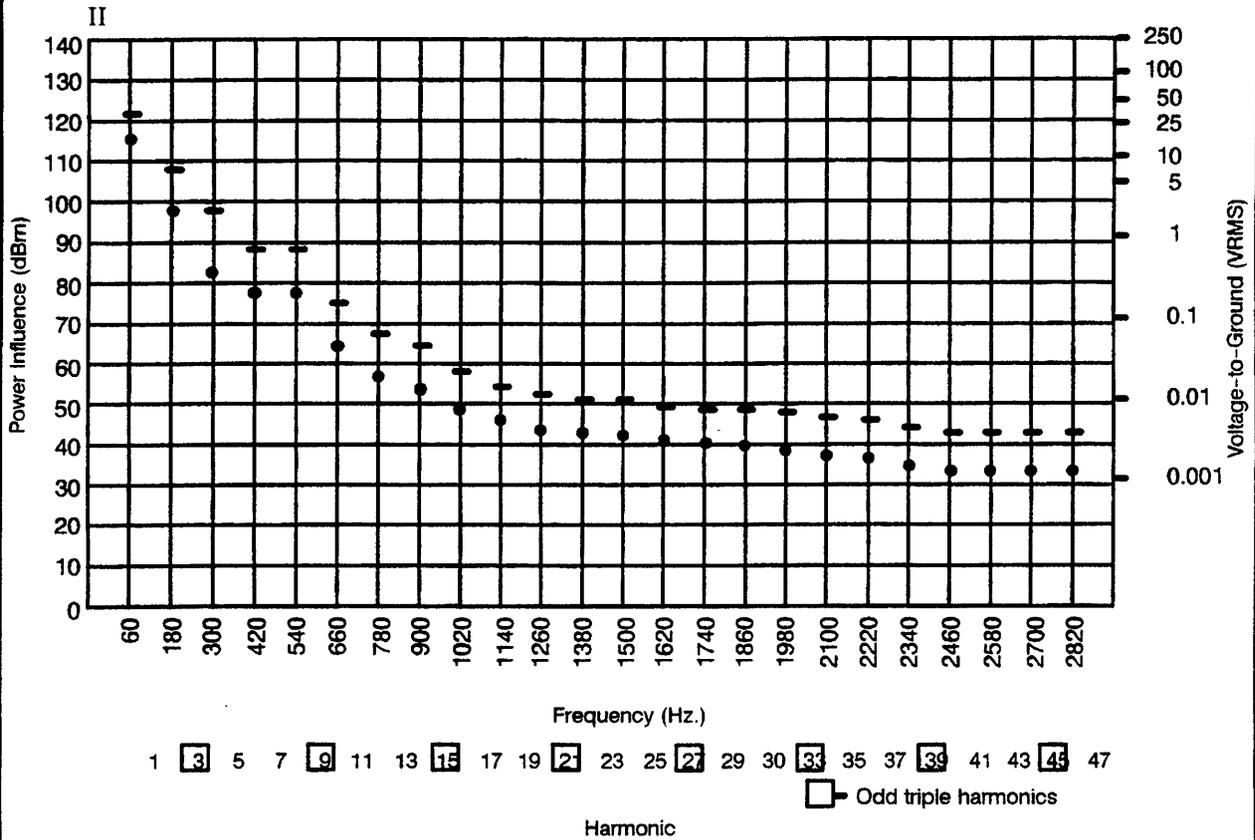


Exhibit 2 - Voltage-to-Ground (VRMS )

# Exhibits, continued

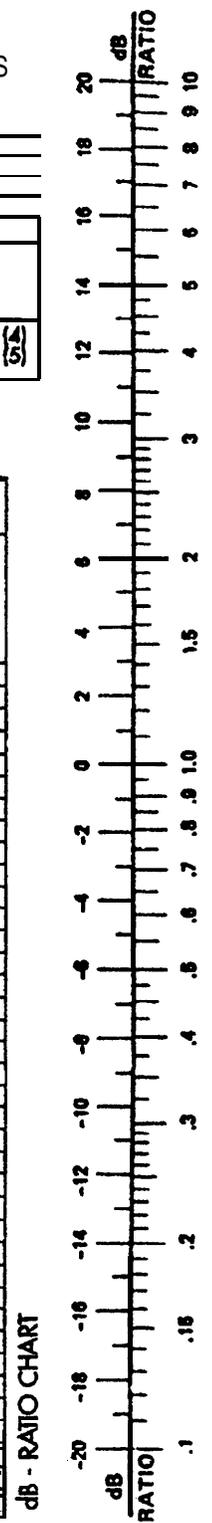
## POWER SYSTEM CURRENT WAVEFORM - HARMONIC ANALYSIS

Central Office: \_\_\_\_\_ Sheet No.: \_\_\_\_\_  
 Power Company: \_\_\_\_\_ Date: \_\_\_\_\_  
 Primary Voltage: \_\_\_\_\_ Time: \_\_\_\_\_  
 Test Location: \_\_\_\_\_ Tester: \_\_\_\_\_  
 Test Condition: \_\_\_\_\_

Ground Return Current  
 100 foot probe wire  
 Probe coil type: \_\_\_\_\_  
 Power Line Hz. (average) \_\_\_\_\_ ft. (4)  
 Correction Factor \_\_\_\_\_ dB (5)

T132 reading, NMS mode, 20/F Weighting black scales \_\_\_\_\_ dB (6).

FREQ. Hz	HARMONIC	TIF Weighted (WEIGHTING switch in C-MSG)			Unweighted (WEIGHTING switch in 20/F)			TIF Contribution	
		T132 reading dB (7)	(7) + (5) If - Wf dBA (8)	If - Wf wtd amps (9)	T132 reading dB (10)	(10) + (5) -40dB = (If) dBA (11)	If amps (12)	(7) - (6) +40dB = (Tf)dB (13)	Tf (14)
60	1								
120	2								
180	3								
240	4								
300	5								
360	6								
420	7								
480	8								
540	9								
600	10								
660	11								
720	12								
780	13								
840	14								
900	15								
960	16								
1020	17								
1140	19								
1380	23								
1500	25								
1620	27								
1740	29								
1860	31								
1980	33								
2100	35								
2220	37								
2340	39								
2460	41								
2580	43								
2700	45								
2820	47								
2940	49								
3060	51								
3180	53								
POWER SUM			(-1)dB	I-T		(0)dBA	I	(11)dB	Tf
NMS									



FOR EACH 20dB MORE POSITIVE, MULTIPLY RATIO BY 10  
 FOR EACH 20 dB MORE NEGATIVE, DIVIDE RATIO BY 10

Exhibit 3 - Power System Current Wave Form - Harmonic Analysis- Data Sheet (C Sheet)

# Exhibits, continued

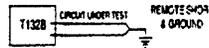
## SPECTRUM ANALYSIS DATA FORM

FORM 887-800-045  
REV. 03-90-045

EXCHANGE: \_\_\_\_\_ LOCATION: \_\_\_\_\_, PAIR NO.: \_\_\_\_\_

HARMONIC	FREQ Hz	POWER INFLUENCE LEVELS**			DISREGARD IF LEVELS ARE LESS THAN (dBmC)	C-WEIGHT ATTENTION FACTOR	NOTES
		1st Test X	2nd Test Y	3rd Test Z			
		DATE TIME	DATE TIME	DATE TIME			
1	60				59	55.7	
2	120				64	37.8	
3	180				69	27.5	
4	240				68	21.2	
5	300				68	16.5	
6	360				68	13.1	
7	420				68	10.5	
8	480				70	8.1	
9	540				71	6.3	
10	600				67	4.7	
11	660				61	3.3	
12	720				58	2.3	
13	780				56	1.6	
14	840				55	1.0	
15	900				54	0.6	
16	960				51	0.2	
17	1020				49	0	
18	1080				47	0.1	
19	1140				45	0.1	
20	1200				44	0.2	
21	1260				43	0.4	
22	1320				43	0.6	
23	1380				42	0.6	
24	1440				42	0.9	
25	1500				41	1.0	
26	1560				41	1.1	
27	1620				40	1.1	
28	1680				40	1.2	
29	1740				40	1.2	
30	1800				39	1.3	
31	1860				38	1.3	
32	1920				38	1.3	
33	1980				37	1.3	
34	2040				37	1.3	
35	2100				36	1.3	
36	2160				36	1.3	
37	2220				36	1.3	
38	2280				36	1.3	
39	2340				36	1.3	
40	2400				35	1.4	
41	2460				34	1.4	
42	2520				34	1.4	
43	2580				34	1.5	
44	2640				34	1.6	
45	2700				35	1.7	
46	2760				34	1.8	
47	2820				33	1.9	

TEST ARRANGEMENT:  
MAKE ALL MEASUREMENTS FROM C/O



(BE CERTAIN TO ADD +40dB FOR PI READINGS)

### SKETCH OF COMMUNICATION & POWER FACILITIES

SHOW: Mileage of both to nearest 1/10 Mile: Type Communication Facility, e.g., Aerial & Buried Cable, Open Wire, etc.: Type Power Exposure, Number of Phases, Delta, Y-MGN, etc.

Instructions: Post 1st, 2nd, and (if required) 3rd spectrum analysis readings on Data Form at left. Extra space is provided for any readings which are not harmonics of 60 Hz. Such readings are normally associated with tone control systems.

Manual Analysis: Identify all readings that exceed "Disregard Levels" and post them in key I of reverse-side Noise Analysis Graph. Examine Area II matrix for best correlation to "Match" boxes (C, D, E, F, G, H, I, J, K, L, M, N, O, P, Q, R, S, T, U, V, W, X, Y, Z). Using the best box-for-box correlations, identify the most probable causes in Area III.

#### OBJECTIVES

QUALITY	PWR INFL (N <sub>g</sub> dBmC +40dB)	CKT NOISE (N <sub>m</sub> dBmC)	BALANCE (b-c)
Acceptable	Less than 80 dBmC	Less than 20 dBmC	Over 50 dBmC
Marginal	80-90 dBmC	20-30 dBmC	50-60 dBmC
Unacceptable	Over 90 dBmC	Over 30 dBmC	Under 50 dBmC

TEST CONDITIONS	POWER INFLUENCE (P <sub>h</sub> )		N <sub>m</sub> dBmC	BALANCE (b-c)
	N <sub>g</sub> FLAT dBmC 3kHz + 40dB	N <sub>g</sub> C dBmC + 40dB		
	a	b		
TEST				
TEST				
3rd TEST				

TROUBLE FOUND

\* Odd Harmonic

\*\* Power Influence levels must be taken in dBmC + 40 dB if the Noise Analysis Chart or the reverse side is used.

Exhibit 4 – Spectrum Analysis Data Form (Page 1 of 2)

# Exhibits, continued

### C-MESSAGE INDUCTIVE COORDINATION-NOISE ANALYSIS CHART (For Problems Not Related to Telephone Circuit Balance or Shield Continuity)

**LEGEND:**

- Marginal
- Mean (L)
- $I^2 \mu = 0$
- $\rho$  Estimated  $\sigma \pm u$
- X First Test
- 2nd Test
- 3rd Test

EXCHANGE \_\_\_\_\_

LOCATION \_\_\_\_\_ FAIR NO \_\_\_\_\_

DATE (S) \_\_\_\_\_

TIME (S) \_\_\_\_\_

BY \_\_\_\_\_

1st Test      2nd Test      3rd Test

Power Influence (dB/Hz)

Power Summation Chart

Notes (See 'Notes' Column Lower Center):

- #1 Usually one (or two adjacent) sets of odd, no-triple harmonics.
- #2 Each higher harmonic deviates more from norm (assuming that all influence harmonics exist at same level).
- #3 Usually observed below 15th harmonic. Can often be helped by moving capacitors closer to substation or using a nitrogenated capacitor configuration.
- #4 Seldom produces harmonics above the 13th.
- #5 One (1) adjacent pair of jagged/harmonics is sufficient to suggest reactor problems.
- #6 420 or 860 Hz may not appear predominantly.
- #7 Sometimes accompanied by protector 'dusting' or shoring. Protector problems are common where power companies experience 'ground fault' earth-pole-throw conditions.
- #8 For long single phase situations, a 1:1 power transformer may provide a solution.
- #9 Usually occurs during periods of 'low demand' for power.
- #10 When harmonic is often predominant.
- #11 Usually occurs during periods of peak power demand.
- #12 If observed frequencies are not exact harmonics of 60 Hz, this may indicate 'air' harmonics from induction motors. If a ripple (120 Hz) from the resonance of two adjacent set frequencies is present, it may be caused by slot effects of 'roving field' generators.
- #13 High 3rd harmonic may come from ballast operated gaseous-discharge lamps (fluorescent, mercury vapor, etc.)
- #14 Customer voltages in excess of 125 - 126V suggest over-rated power transformer(s).

POWER SUMMATION CHART

NOTES (See 'Notes' Column Lower Center):

- #1 Usually one (or two adjacent) sets of odd, no-triple harmonics.
- #2 Each higher harmonic deviates more from norm (assuming that all influence harmonics exist at same level).
- #3 Usually observed below 15th harmonic. Can often be helped by moving capacitors closer to substation or using a nitrogenated capacitor configuration.
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- #6 420 or 860 Hz may not appear predominantly.
- #7 Sometimes accompanied by protector 'dusting' or shoring. Protector problems are common where power companies experience 'ground fault' earth-pole-throw conditions.
- #8 For long single phase situations, a 1:1 power transformer may provide a solution.
- #9 Usually occurs during periods of 'low demand' for power.
- #10 When harmonic is often predominant.
- #11 Usually occurs during periods of peak power demand.
- #12 If observed frequencies are not exact harmonics of 60 Hz, this may indicate 'air' harmonics from induction motors. If a ripple (120 Hz) from the resonance of two adjacent set frequencies is present, it may be caused by slot effects of 'roving field' generators.
- #13 High 3rd harmonic may come from ballast operated gaseous-discharge lamps (fluorescent, mercury vapor, etc.)
- #14 Customer voltages in excess of 125 - 126V suggest over-rated power transformer(s).

IV. NOTES (See 'Notes' Column Lower Center):

SEE NOTE #1

SEE NOTE #1	PROBABLE CAUSE
#7, #8	1. Poorly balanced 30 phase system or too much exposure to single phase circuits, or one or two capacitors of a 30 capacity not working
#2	2. Open cable shield.
#6	3. Misfunctioning capacitor bank.
#3, #13	4. Core resonance. Usually aggravated by presence of capacitor bank.
#4, #14	5. Existing current in distribution transformers (aluminum core), possibly aggravated by C.F.A. resonance resulting from presence of shunt capacitors.
#9, #10, #14	6. Overrated power transformer.
	7. Defective power step-down transformer.
#13	8. Grounded 30 transformer or transformer equipped with no. 10 (insulation) primary or 25.00 to a grounded 120 transformer - when aggravated by grounded capacitors.
#1, #12	9. Balanced harmonics from generator or synchronous motor or condenser.
	10. SCR control devices.
	11. Defective (and/or over-rated) power transformer(s).
#5	12. AC side of 60 rectifier or SCR control devices.
	13. DC side of 60 rectifier.
#5	14. AC side of 20 rectifier.
	15. DC side of 120 rectifier.
#5	16. Other multiphase rectifier (AC lines).
#13	17. Susceptible reactor devices in 10 reactors, vapor lamps, reactors, frequency changers, power tools, induction heaters, etc.
#3	18. Resonance in balanced or radial circuit of power system (may be due to short on conductors).
#1	19. Pinger gas tubes being (also usually related to cause 1, above).
#21	20. Electronic frequency converters (inverter-converter).

○ = Capacitor Related;    △ = Transformer Related;    □ = Other;    ⊕ = May vary from source harmonic - See Note #12;    ○ = Odd triple harmonics

Exhibit 4 Spectrum Analysis Data Form (Page 2 of 2)

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