01 Apr 1991

# Bundled Cable Parameters and Their Impact on EMI Measurement Repeatability

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# BUNDLED CABLE PARAMETERS AND THEIR IMPACT ON EMI MEASUREMENT REPEATABILITY

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**ABSTRACT** - This research project was 99% experimental, therefore, not many theoretical ideas will be presented. The main idea behind the project was centered around cable bundling. The effect of cable bundling using analytical measurements and data from a network analyzer was investigated.

**INTRODUCTION** - The FCC has stated Electro-Magnetic Interference (EMI) test procedures for cable bundling observation. The standard procedure states specifics about cable length and the location of the bundles. Cable bundles are to be "30 to 40 centimeters" in length and located near the center of the long cable. It also states they should be bundled in "serpentine fashion". Parameters such a tightness, shape and the number of loops are not specified.

Because of this vagueness, the testing results were not repeatable. This paper delves in to find more specifics and to view the effects of various bundling.

**DESCRIPTION OF SET-UP** - A simplified model was constructed using a coaxial cable attached to an insulated wire. The wire acted as an antenna. It measured three meters in length. Analyzing the basic physical changes in the antenna, one can grasp the effects of the tightness and shape parameters. Although the data taken is not ideal given the experiment was not performed in a vacuum, approximations could be made. Ferrite cores were used to limit the noise; and the set-up, other than the antenna, was held constant for each measurement. These factors limited the error. The network held constant is shown in Figure 1.

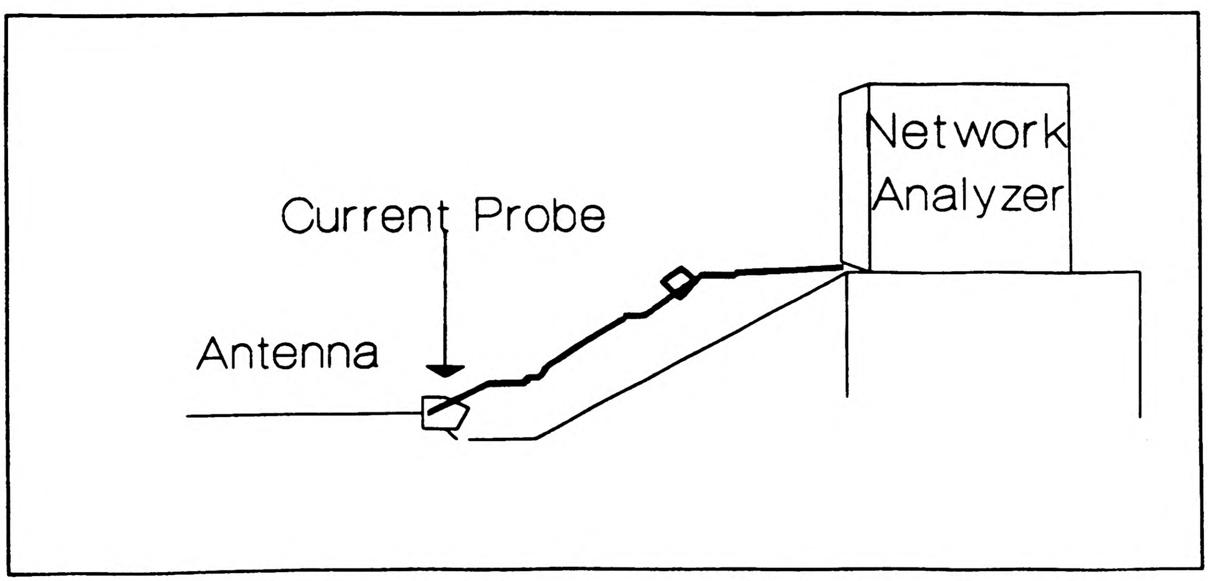



**Figure 1**: Simplified EMI Source Model

Originally the coaxial cable was the "bundling cable"; yet, after prolonged experimentation and observation, it became obvious this method would not work without a controlled environment. Therefore, the changing of the antenna and the formation of a transmission line were observed. This was another method by which bundling could be experimented with. Using this method, clear and precise results were found.

The resonant frequencies were sought out, using a small voltage driven by an unknown source attached to the cable and antenna, thereby creating a high current. This current was detected by a current probe located where the cable met the antenna. (See Figure 1.) The reading was displayed on the CRT as current verses frequency. Here, the peaks of the signal were the locations of the resonant frequencies. Resonant frequencies occur at frequencies where the length of the antenna (wire) is approximately one-quarter wavelength. The changes in the bundling of the antenna became very apparent using this displayed signal.

**RESULTS** - The following pages are the founded results of the experimentation completed by creating a transmission line and changing its length, width, and placement on the antenna. Finally, simple changes were observed in the bundles.

First, the straight antenna:

| Null | Resonant Frequency Location (MHz) |
|---|---|
| 1 | 37.001197 |
| 2 | 75.991098 |
| 3 | 120.286096 |
| 4 | 145.437353 |

**Table 1**

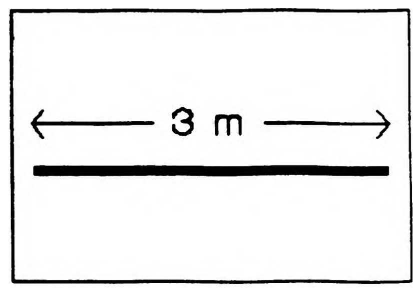



**Figure 2**

Refer to Graph 1. The respective signal is represented with a circled 1.

Second, the original transmission line:

| Null | Resonant Frequency Location (MHz) |
|---|---|
| 1 | 43.488164 |
| 2 | 68.312838 |
| 3 | 120.674397 |
| 4 | 144.775385 |

**Table 2**

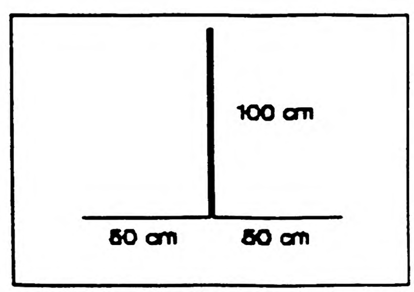



**Figure 3**

Refer to Graph 1. The respective signal is represented with a circled 2.

Third, a change in the transmission line's width:

| Null | Resonant Frequency Location (MHz) |
|---|---|
| 1 | 42.607466 |
| 2 | 72.468449 |
| 3 | 122.865976 |
| 4 | 143.286033 |

**Table 3**

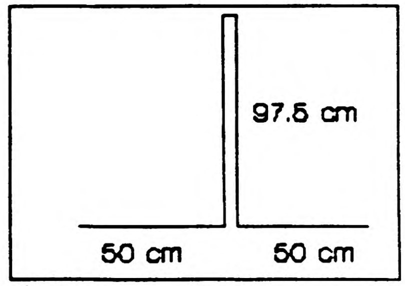



**Figure 4**

Refer to Graph 1. The respective signal is represented with a circled 3.

Fourth, a second change in the transmission line's width:

| Null | Resonant Frequency Location (MHz) |
|---|---|
| 1 | 39.906895 |
| 2 | 74.924578 |
| 3 | 119.848397 |
| 4 | 144.707873 |

**Table 4**

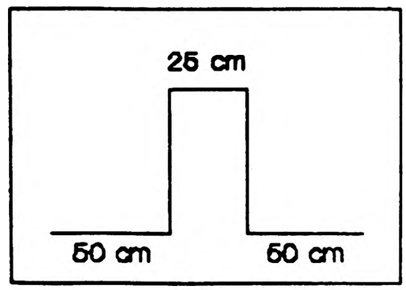



**Figure 5**

Refer to Graph 1. The respective signal is represented with a circled 4.

Fifth, a change in the length of the transmission line:

| Null | Resonant Frequency Location (MHz) |
|---|---|
| 1 | 43.910144 |
| 2 | 82.812232 |
| 3 | 125.272427 |
| 4 | 162.795557 |

**Table 5**

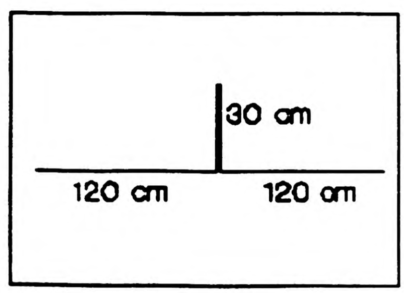



**Figure 6**

Refer to Graph 2. The respective signal is represented with a circled 1.

Sixth, a second change in the length of the transmission line:

| Null | Resonant Frequency Location (MHz) |
|---|---|
| 1 | 43.412667 |
| 2 | 76.625817 |
| 3 | 113.661067 |
| 4 | 179.274797 |

Table 6

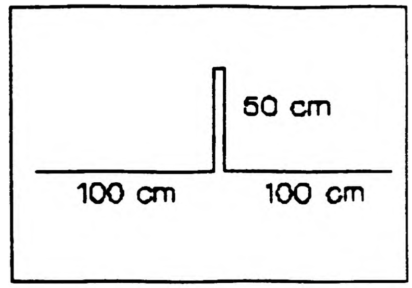



Figure 7

Refer to Graph 2. The respective signal is represented with a circled 2.

Seventh, a third change in the transmission line's length:

| Null | Resonant Frequency Location (MHz) |
|---|---|
| 1 | 43.413118 |
| 2 | 71.487329 |
| 3 | 112.224305 |
| 4 | 170.273529 |

Table 7

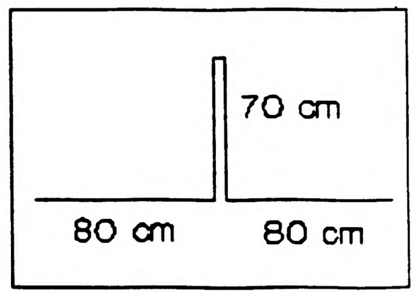



Figure 8

Refer to Graph 2. The respective signal is represented with a circled 3.

Eighth, a move in the transmission line's location:

| Null | Resonant Frequency Location (MHz) |
|---|---|
| 1 | 41.347888 |
| 2 | 74.955529 |
| 3 | 112.224305 |
| 4 | 146.235965 |

Table 8

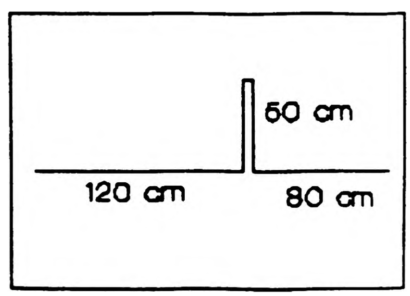



Figure 9

Refer to Graph 3. The respective signal is represented with a circled 1.

Nineth, a second move in the trasmission line's location:

| Null | Resonant Frequency Location (MHz) |
|---|---|
| 1 | 41.402628 |
| 2 | 85.131639 |
| 3 | 116.489545 |
| 4 | 145.932195 |

**Table 9**

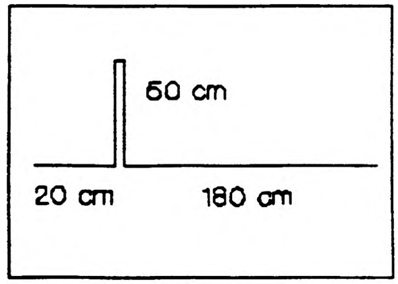



**Figure 10**

Refer to Graph 3. The respective signal is represented with a circled 2.

Lastly, a third move in the transmission line's location:

| Null | Resonant Frequency Location (MHz) |
|---|---|
| 1 | 41.860077 |
| 2 | 80.287814 |
| 3 | 109.111117 |
| 4 | 145.379895 |

**Table 10**

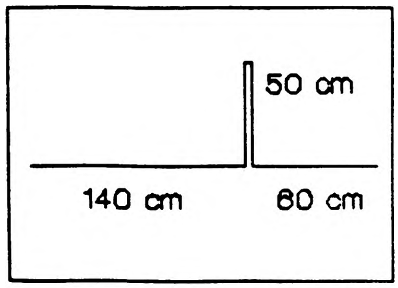



**Figure 11**

Refer to Graph 3. The respective signal is represented with a circled 3.

The final observation was changing the "bundles" of the transmission line. The circled 1 representation on Graph 4 is the original transmission line. The transmission line was bent. See table of resonant frequencies and figure below.

| Null | Resonant Frequency Location (MHz) |
|---|---|
| 1 | 44.267112 |
| 2 | 68.334523 |
| 3 | 120.978555 |
| 4 | 195.979618 |

**Table 11**

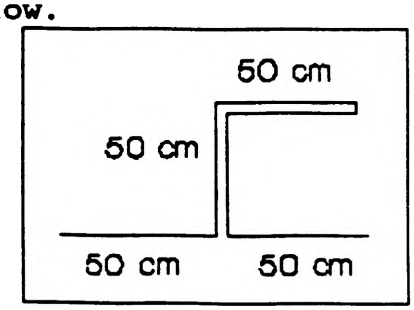



**Figure 12**

The second and final change in the transmission line bundle is represented on Graph 4. See the signal marked with the circled 3. The data is in the following table and the diagram is presented below.

| Null | Resonant Frequency Location (MHz) |
|---|---|
| 1 | 45.975133 |
| 2 | 67.753367 |
| 3 | 116.562962 |
| 4 | 198.867048 |

**Table 12**

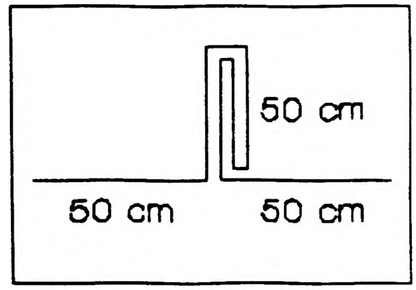
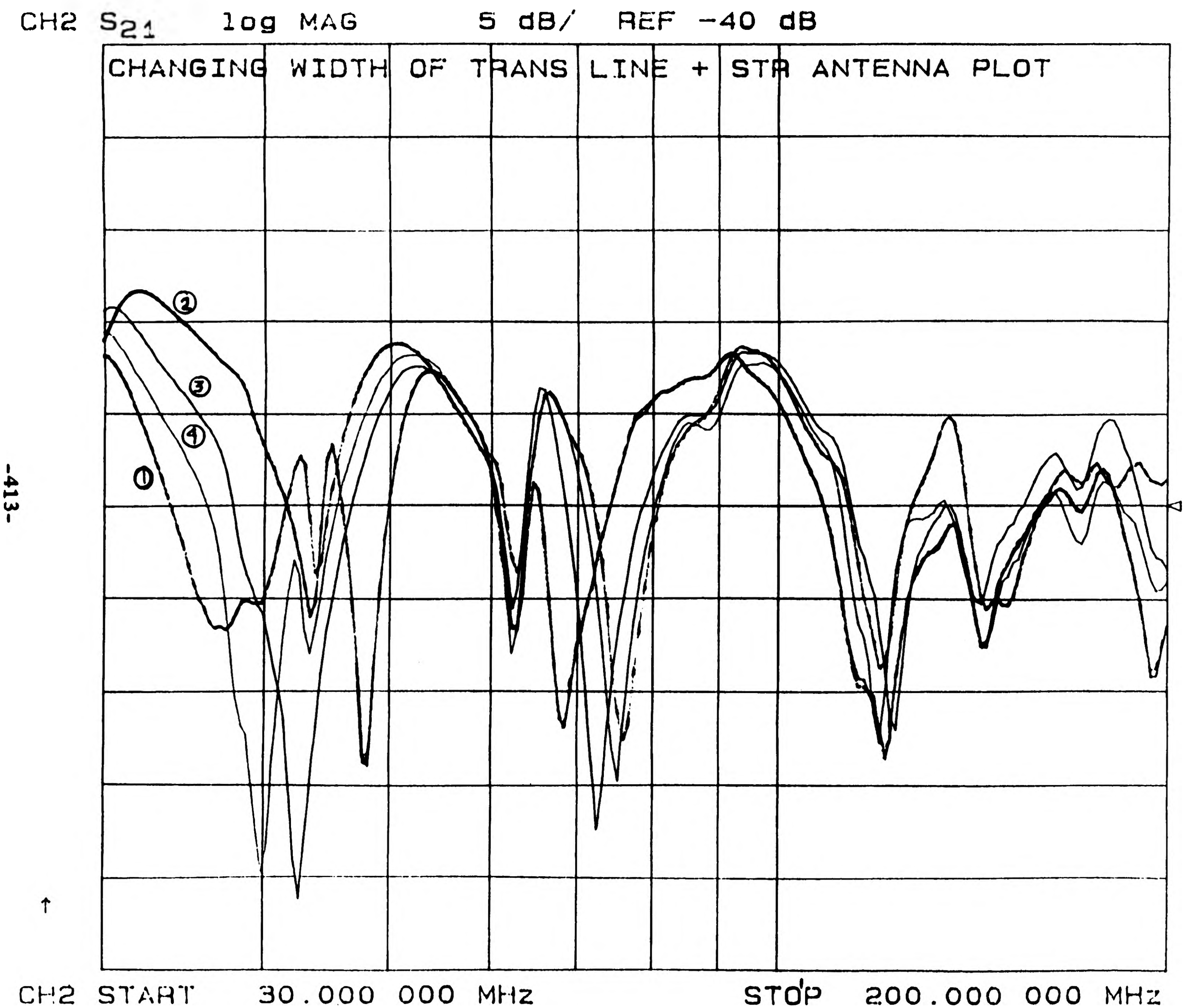


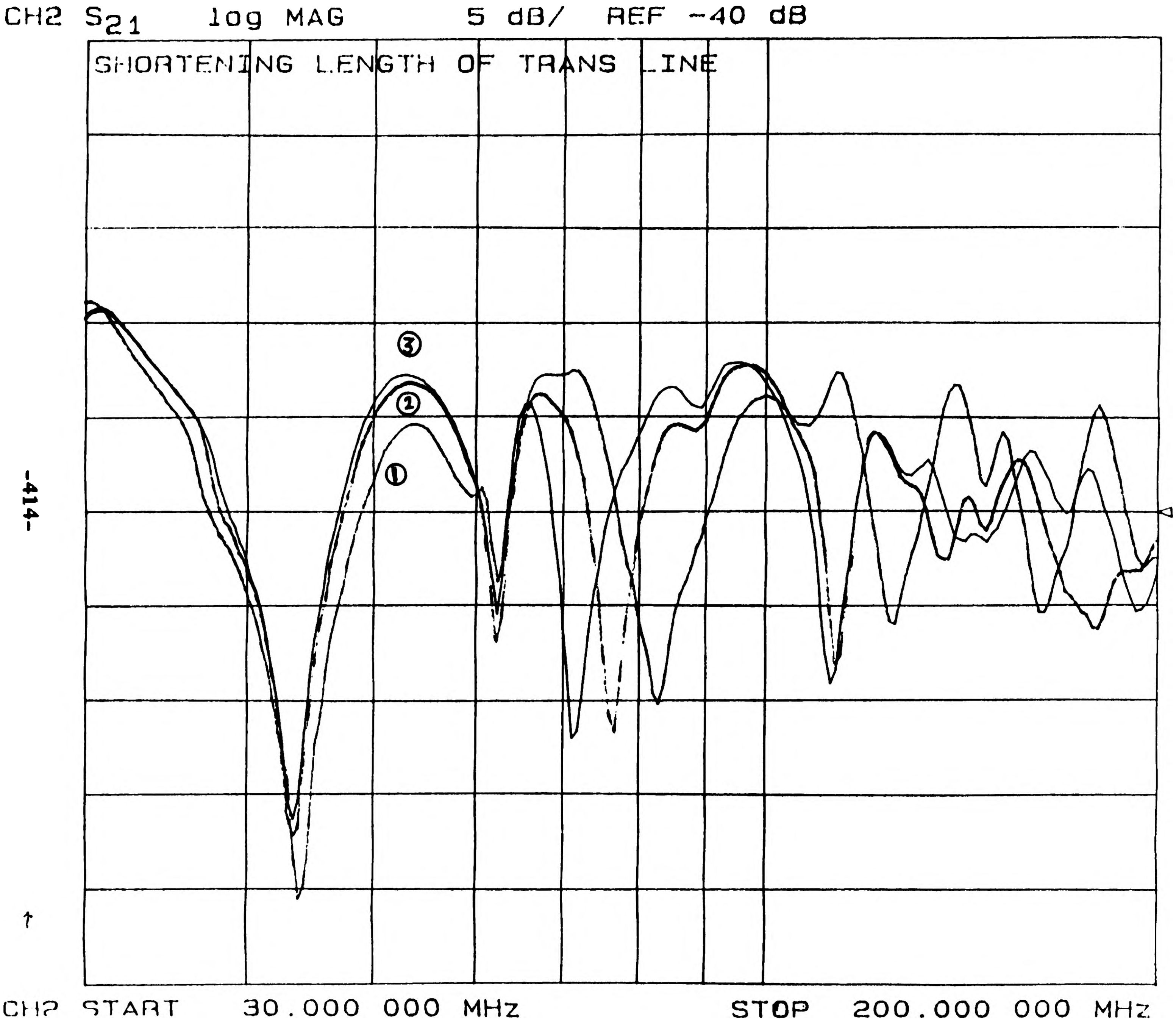

**Figure 13**

CONCLUSIONS - There is much consistency in the resonant frequency locations when the width of the transmission line was varied. In changing the length, again we had consistency at low frequencies but at high frequencies there were discrepancies. When the location varied, the resonant frequency locations stayed relative to the original transmission line. Bundling also gave results that did not vary much from the results of the original transmission line at low frequencies; yet, at higher frequencies the resonant frequency peaks changed dramatically. However, in the changes of the bundles observed in this paper, change is found among the resonant frequency locations from bundle to bundle; therefore justifying the need for more specific parameters when dealing with bundled cables.

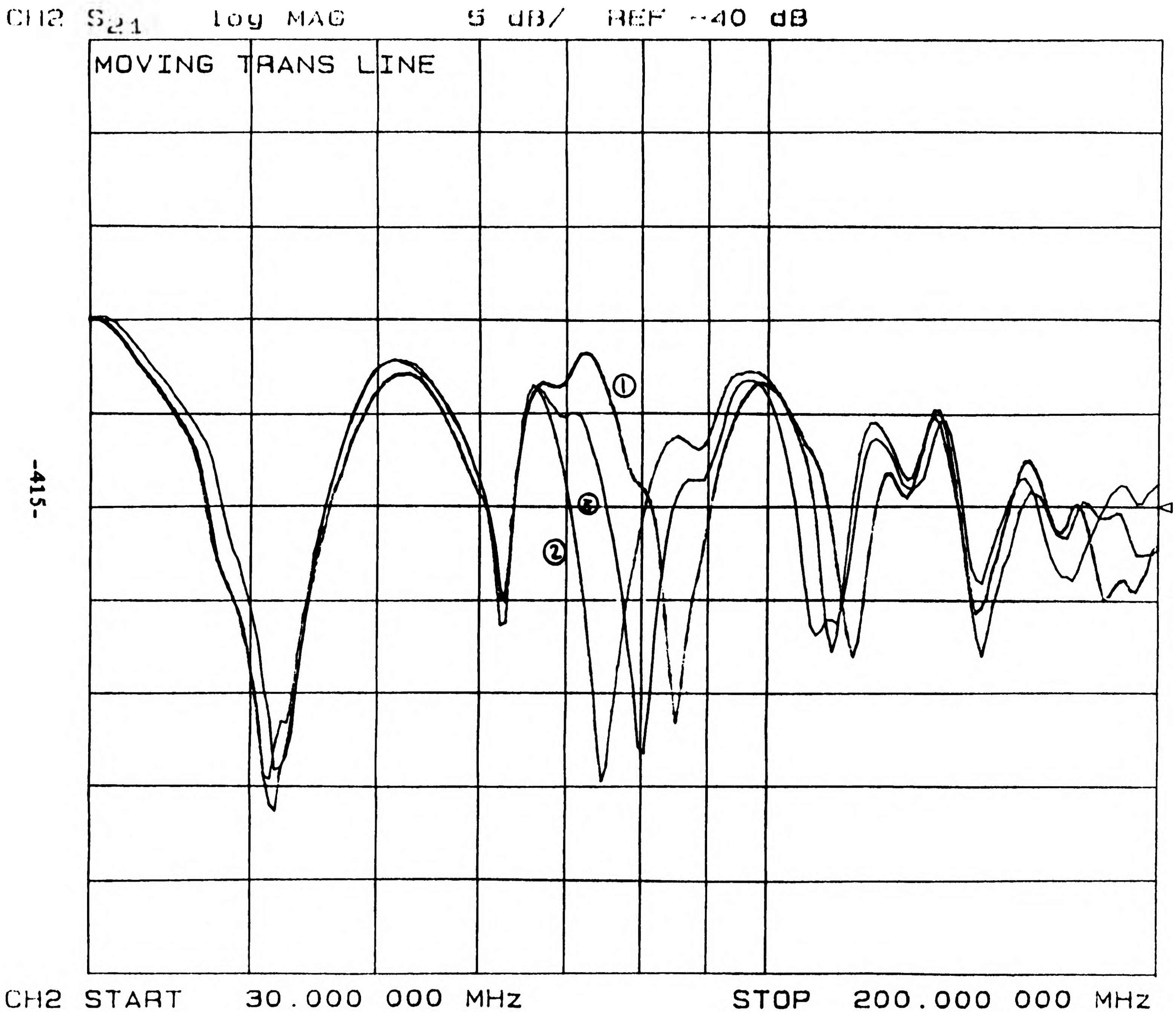
Further research can be done in manipulating the computer program already established to give resonant frequencies of the transmission lines created in this project. This program was not used throughout this experiment. It must be developed further. This would provide more data for comparison and allow specific parameters to be developed and included in the FCC standards.


CH2 $S_{21}$ log MAG 5 dB/ REF -40 dB
CHANGING WIDTH OF TRANS LINE + STR ANTENNA PLOT
①
②
③
④
CH2 START 30.000 000 MHz
STOP 200.000 000 MHz

Graph 1

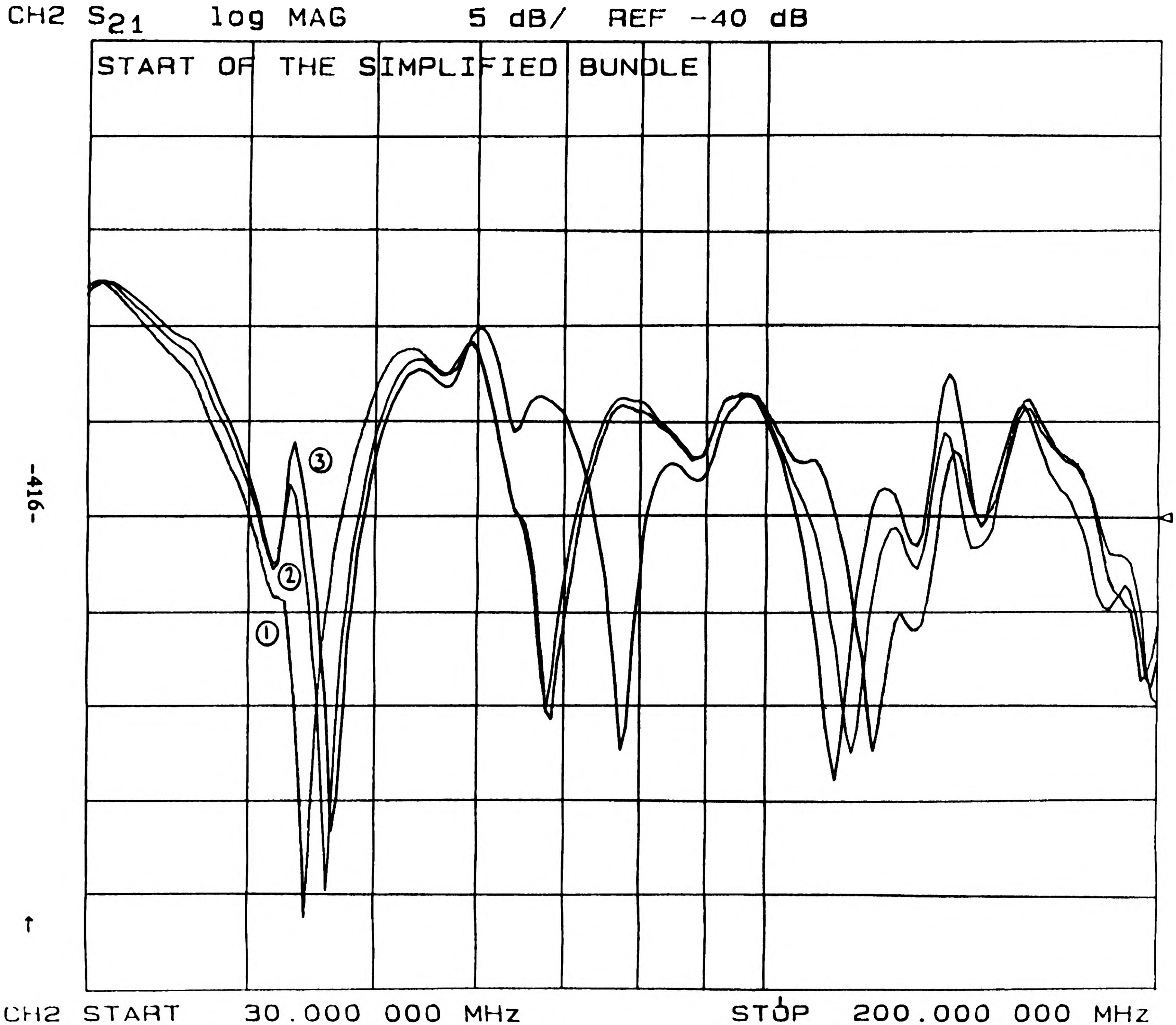

CH2 $S_{21}$ log MAG 5 dB/ REF -40 dB
SHORTENING LENGTH OF TRANS LINE
③
②
①
CH2 START 30.000 000 MHz
STOP 200.000 000 MHz

Graph 2


CH2 S21 log MAG 5 dB/ REF -40 dB
MOVING TRANS LINE
CH2 START 30.000 000 MHz
STOP 200.000 000 MHz



Graph 3


CH2 S21 log MAG 5 dB/ REF -40 dB
START OF THE SIMPLIFIED BUNDLE
①
②
③
CH2 START 30.000 000 MHz
STOP 200.000 000 MHz

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Graph 4