Engineering Report

in Support of Certification FCC Form 731
for MCUB5R radiomodem

Subject:	Compliance of Radio Modem with Respect to FCC Rules & Regulations Parts 2 and 90 Certification FCC Form 731
Equipment:	UHF Radio Modem
FCC Id:	EOTMCUB5R
Applicant:	Dataradio Inc. 5500 Royal Mount Ave., Suite 200 Town of Mount Royal, H4P 1H7 Quebec, Canada

April 16, 1999
Dataradio Inc

Johnson Data Telemetry Corporation
Waseca, Minnesota

ENGINEERING STATEMENT OF MARK CHRISTENSEN

The application consisting of the attached engineering exhibit and associated FCC form 731, has been prepared in support of a request for Type Acceptance for the Johnson Data Telemetry (JDT) DL-3412, 403-512 MHz Transceiver with the Data Radio 3315(Integra) Modem. The Transceiver mated with the Integra Modem will be identified by the part number INA12XY0T where X represents range and Y represents IF bandwidth (see below for part#). The model name is MCUB5R. The Transceiver/Modem will be identified by the FCC number EOTMCUB5R. The transceiver operates pursuant to Part(s) 90 and 15 of the Rules and Regulations.

EXISTING CONDITIONS

The units utilized for these type acceptance measurements were obtained from the pilot-production. The transceiver is designed to operate on frequencies ranging from 403.000 MHz to 512.000 MHz. The frequency tolerance of the transceiver is .00015% or 1.5 parts per million. The frequency stability of the transceiver is controlled by a temperature compensated crystal oscillator (TCXO) operating at 17.5 MHz.

PROPOSED CONDITIONS

It is proposed to Type Accept the MCUB5R, 403-512 MHz Transceiver/Modem for operation in the band of frequencies previously outlined. The applicant anticipates marketing the device for use in wireless transmission of data.

PERFORMANCE MEASUREMENTS

All Type Acceptance measurements were conducted in accordance with the Rules and Regulations Section 2.1041of Pike & Fischer Inc., CD ROM revision 9/28/98. Equipment performance measurements were made in the engineering laboratory and on the FCC certified Open Area Test Site at the Transcrypt International / E.F. Johnson Radio Products located at 299 Johnson Avenue in Waseca, Minnesota. All measurements were made and recorded by myself or under my direction. The performance measurements were made between Jan 28, 1999 and Feb 8,1999.

CONCLUSION

Given the results of the measurements contained herein, the applicant requests that Type Acceptance be granted for the INA12XY0T, 403-512 MHz Transceiver/Modem as tested for data communications.

4/5/99

Mark Christensen
Director of Engineering, Johnson Data Telemetry

Part Number

X	Freq Range
1	380-403 MHz
2	403-419 MHz
3	419-435 MHz
4	435-451 MHz
5	450-470 MHz
6	464-480 MHz
7	480-496 MHz
8	496-512 MHz

Y	IF Bandwidth
1	12.5 KHz
3	25 KHz

QUALIFICATIONS OF ENGINEERING PERSONNEL (2.911)

NAME:	Allen Frederick
TITLE:	Certified Technologist
TECHNICAL EDUCATION:	Bachelor of Science Degree in Electronic Engineering Technology (1998) from Mankato State University
TECHNICAL EXPERIENCE:	2 years experience in analog and radio frequency communications

NAME:	Constantin Pintilei
TITLE:	R&D Test Engineer
TECHNICAL EDUCATION:	Bachelor of Science Degree in Radiotechnique Electronic Engineering (1993) from Technical University of Iasi, Romania
TECHNICAL EXPERIENCE:	5 years experience in radio frequency measurements

Contents

Engineering Summary

This report contains the results of the engineering evaluation performed on a Dataradio Inc. radio modem, having a frequency range of 403-512 MHz, model MCUB5R. Johnson Data Telemetry (JDT) Corporation carried out the tests in accordance with FCC Rules and Regulation Part 2 and Part 90.

The radio modem was evaluated for output power levels of 1 and 5 watts.

Based on test results, it is certified that the product meets the requirements as set forth in the above specifications for Certification.

The MCUB5R UHF radio modem is comprised of a Dataradio 3315 loader/modem board and a DL 3412 Telemetry transceiver. Test data and graphs for this configuration are presented in this report.

General Information

FCC submission information

FCC Id:	EOTMCUB5R
Equipment:	UHF radio modem
Model:	MCUB5R
Applicant:	Dataradio Incorporated 5500 Royal Mount Ave., Suite 200 Town of Mount Royal, H4P 1H7 Quebec, Canada
Manufacturer	Dataradio Incorporated 5500 Royal Mount Ave., Suite 200 Town of Mount Royal, H4P 1H7 Quebec, Canada
Test laboratory	Johnson Data Telemetry Corporation (JDT) 299 Johnson Ave. SW Waseca , MN 56093

Manufacturer's data

Equipment:	UHF radio modem
Model:	MCUB5R
Serial Number:	xxxx (prototype serial)
Reference:	FCC Rules and Regulations Part 2 and Part 90
Manufacturer:	Dataradio Incorporated

Product's general specifications

1	Frequency range	403-512 MHz	
2	Rated transmitted output power	1 - 5W	
3	Data modulation	DRCMSK	
4	Channel spacing	25 KHz	12.5 KHz
5	Emission type	15K3 F1D	9K30 F1D
6	Frequency deviation	±4 KHz	±2.5 KHz
7	Data rate	19200 bps	9600 bps
8	Antenna impedance	50 Ω	
9	Power source	13.3 V	

Information for Certification

Ref: FCC Part 2 paragraph 2.1033 (c)

1. Name of Applicant:

Ref: FCC Part 2 paragraph 2.1033 (c)(1)

Applicant:	Dataradio Incorporated 5500 Royal Mount Ave., Suite 200 Town of Mount Royal, H4P 1H7 Quebec, Canada
Manufacturer	Same as applicant

2. FCC Identifier

Ref: FCC Part 2 paragraph 2.1033 (c)(2)

Model No.:	MCUB5R, comprised of two boards: MCU 3315 (Dataradio 210-03315-0xx)- modem board DL 3412 (JDT 242-3412-xx0)- transceiver board
Serial No.:	xxxx (prototype serial) xxx-3315-0xx-modem board 3412- xxxxxx-5x0-transceiver board
FCC Id:	EOTMCUB5R

3. Instruction book

Ref: FCC Part 2 paragraph 2.1033 (c) (3)

See technical manual in Integra-TR Technical Manual, Attachment D,

4. Types of emission

Ref: FCC Part 2 paragraph 2.1033(c)(4)

Channel spacing	25 KHz	12.5 KHz
Emission type	15K3 F1D	9K30 F1D
Frequency deviation	±4 KHz	±2.5 KHz

5. Frequency range

Ref: FCC Part 2 paragraph 2.1033(c)(5)

403-512 MHz

6. Range of operating power levels

Ref: FCC Part 2 paragraph 2.1033(c)(6)

The power is adjusted at the manufacturer at a level of 5W.

7. Maximum Power rating

Ref: FCC Part 2 paragraph 2.1033(c)(7)

5 Watts

8. DC voltages and currents into final amplifier

Ref: FCC Part 2 paragraph 2.1033(c)(8)

Refer also to RF output and DC input power measurement in section “Test Results”.

9. Tune-up procedure

Ref: FCC Part 2 paragraph 2. 1033(c)(9)

1. Connect the transceiver to be aligned to a DC power source. A DC current meter capable of measuring at least 2.5 Amps should be connect in line with the DC source. Connect the output of the transceiver through a watt meter and into a 50 ohm dummy load.

2. Load the synthesizer with the center channel frequency.

3. Key the transmitter and make certain that the supply voltage at the RF board is 13.3 VDC. (Do not transmit for extended periods of time.)

4. Adjust R535 clockwise for 5.0 Watts of output power.

5. Check the power levels on the low and the high frequencies for 5.0 Watts +/- 1 Watt.

10. Complete circuit diagram, circuitry and devices for determining and stabilizing frequency, circuits for suppression of spurious radiation, limiting of modulation and limiting of power

Ref: FCC Part 2 paragraph 2. 1033(c)(10)

For the main control circuits and the modem circuits see the section Dataradio MCU modem, in Description of Circuitry, Attachment A part 1.

For the transceiver circuits see the section JDT DL-3412 Telemetry Transceiver, in Description of Circuitry, Attachment A part 2.

Circuitry’s mainly involved in determining and stabilizing frequency are VCO block and Synthesizer block described in Transceiver’s part.

i) spurious radiation- The main suppression of spurious radiation is performed by the filter described in “Low Pass Filter” paragraph from JDT DL-3412 Telemetry Transceiver, Description of Circuitry part 2, Attachment A

ii) limiting of modulation- Limiting of modulation is given by amplitude limited audio signal provided by modem part as it was explained in “Modem” paragraph from Dataradio MCU modem, Description of Circuitry part 1, Attachment A. Supplementary limiting of modulation is described in “ Frequency Modulation” paragraph from Synthesizer section JDT DL-3412 Telemetry Transceiver, Description of Circuitry part 2, Attachment A.

iii) limiting of power- A very tight control of transmission power is maintained by circuitry described in “Power Control” paragraph from JDT DL-3412 Telemetry Transceiver, Description of Circuitry part 2, Attachment A

See schematics in Schematics, Attachment B

11. Equipment identification plate/label

Ref: FCC Part 2 paragraph 2.1033(c)(11)

A scanned image of the Equipment identification label is provided in Photographs, Attachment C

12.Photographs of the equipment

Ref: FCC Part 2 paragraph 2.1033 (c)(12)

All scanned photographs of the Equipment are provided in Photographs, Attachment C

13. Digital modulation techniques

Ref: FCC Part 2 paragraph 2.1033 (c) (13)

The digital modulation used by the MCU modem is DRCMSK (Differential Raised Cosine Minimum Shift Keying). A modem using such type of modulation is divided in three main units. They are:

1. Scrambler,
2. Differential encoder,
3. Waveshape generator.

We will explain each of those units, starting with the scrambler.

1. Scrambler:

The scrambler converts data stream to a new data stream having better characteristics for a FM radio system. Here are the main advantages:

-It removes the DC component from a DRCFSK signal,

-It randomizes the data in such a way we can avoid predictable patterns, by example:

00000000, 111111111, 01010101, 00110011, etc.

-It keeps the power spectrum more compact by avoiding sequences like 01010101…

All these functions are performed with a serial shift register and 2 exclusive OR gates that implement the polynomial form X^7+X^5-1. The receiver side of our radio modems has a similar circuit called descrambler to decode the received scrambled data.

2. Differential encoder:

After data is scrambled, we encode the data with a differential encoder. Here is the process that differential encoder does:

previous input bit	current input bit	output bit
0	0	0
0	1	1
1	0	1
1	1	0

Example:

From a sequence of 01001011110100010101000010, differentially encoded data stream is:

110111000111001111110011.

The differential encoder is used to make the modem insensitive to audio polarity inversion of the FM radio system.

3. Waveshape generator:

The waveshape generator converts the processed data bits (scrambled and differentially encoded for DRCMSK) to the audio signal that will modulate a FM transmitter. This gives the DRCMSK waveshape having a compact spectrum to fit inside FCC Part 90 masks according to the channel bandwidth intended.

Furthermore, the modem itself generates a RF signal heading the transmission in normal usage and a test pattern for test purposes.

1. Transmission preamble:
Each data transmission begins by sending a 15ms preamble of sinewave (101010…). This is to synchronize the digital phase looked loop of the receiver modem.
2. Test pattern generator:
A 30s test pattern sequence is generated by test software at "test data" click button event. According to the baud rate, the highest resulting modulating frequency is (baud rate)/2 Hz. The sequence is sent with baud rate speed, and its data has the pattern:

###ABCDEFGHIJKLMNOPQRSTUVWXYZabcdefghijklmnopqrstuvwxyz0123456789\r\n,

repeated for 30 seconds.

14. Test data

Ref: FCC Part 2 paragraph 2.1033 (c)(14)

All applicable test data according to:
-Part 2: 2.1046, 2.1047, 2.1049, 2.1051, 2.1053, and 2.1057
-Part 90, Subpart I: 90.209, 90.210, 90.211, 90.213 and 90.214
are provided in section Test Results of this Engineering Report

15. Other data

For data according to 2.1033(c)(15,16), this unit is not designed for the mentioned purposes.

Tests Results for MCUB5R radio modem

NAME OF TEST: Transmitter Rated Power Output

RULE PART NUMBER: 2.1033 (c)(6)(7) and 2.1046 (a)

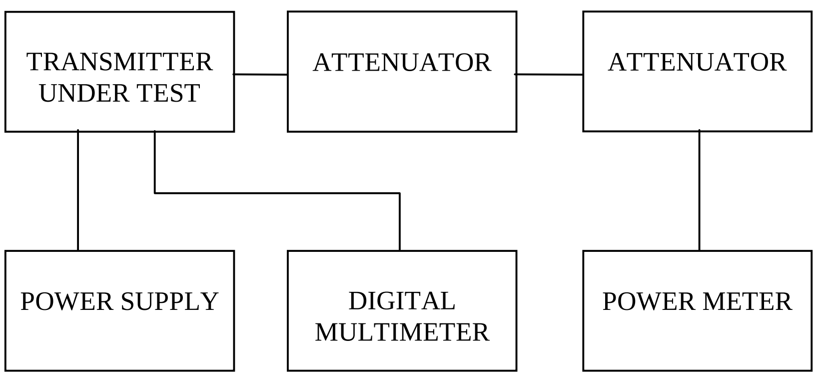
TEST RESULTS: See results below

TEST CONDITIONS: Standard Test Conditions, 25 C

TEST EQUIPMENT:
Attenuator, BIRD Model / 9715 / 50-A-MFN-06 / 6 dB / 50 Watt
Attenuator, BIRD Model / 9716 / 25-A-MFN-20 / 20 dB / 25 Watt
Digital Voltmeter, Fluke Model 8012A
DC Power Source, Model HP6284A
Power Meter, Hewlett Packard 436A

PERFORMED BY: ______________________ DATE: 2/2/99
Allen Frederick

TEST SET-UP:



TEST RESULTS:

Frequency (MHz)	DC Voltage at Final (VDC)	DC Current into Final (ADC)	DC Power into Final (W)	RF Power Output (W)
450.000	13.3	1.75	23.28	5.0

NAME OF TEST: Transmitter Occupied Bandwidth

RULE PART NUMBER: 2.201, 2.202, 2.1033 (c)(14), 2.1049 (h), 2.1041

Necessary Bandwidth Measurement

This radiomodem uses digital modulation signals, passing through a linear 8th order low-pass filter (Raise-Cosine alpha 1 approximation), to an FM transceiver. The necessary bandwidth calculation for this type of modulation (DRCMSK) is not covered by paragraphs (1), (2) or (3) from 2.202(c). Therefore, the approach outlined in (2.202(c)(4)) is applicable in this case.

The measurement explanations are provided in "Annex " (following pages)

Necessary Bandwidth Measurement:

Peak deviation = ±4 kHz
Modulator signal bit rate 19200 bps,

Bn=15260 Hz
The corresponding emission designator prefix for necessary bandwidth = 15K3

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Table 1 - Measurements results for the INTEGRA unit , 9600 bps BT.3 and 19200 bps BT.3 and frequency deviations set to obtain specified values .

unit's software settings	measured data (kHz)		Emission designator
bit rate (data settings)	freq. dev	99% occupied BW	
9600 BT.3	3.0	9.24	9K30
19200 BT.3	4.0	15.26	15K3

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Also, Spectrum Efficiency (90.203 (j)(3)) requirement: 4800 bits per second per 6.25 kHz of channel bandwidth.
19200bps=4*4800bps so it is efficient for 25 kHz channel
9600bps=2*4800bps so it is efficient for 12.5 kHz channel

ANNEX

Theory of Measurement

The way to define the ***Occupied Bandwidth*** is “the frequency bandwidth such that, below its lower and above its upper frequency limits, the mean powers radiated are each equal to 0.5 percent of the total mean power radiated by a given emission” (FCC 2.202), the mathematics are as follows:

$$0.005*TP=P_{(f1)}=\int_0^{f1} PSD_{(f)}df$$

$$0.995*TP=P_{(f2)}=\int_0^{f2} PSD_{(f)}df$$

OBW=f2-f1

where TP (total mean power) is

$$TP=\int_0^{+\infty} PSD_{(f)}df =(1/t)\int_{-\infty}^{+\infty} |z_{(t)}|^2dt$$

and PSD (power spectral distribution) is

$$PSD_{(f)}=|Z_{(f)}|^2+|Z_{(-f)}|^2 \qquad 0\leq f<4$$

and expresses the positive frequency representation of the transmitter output power for z(t) signal.

By applying these mathematics to the measurements, it is possible to measure the Occupied Bandwidth using the RF signal’s trace provided by a digital spectrum analyzer and processed further by computational methods.

The Occupied Bandwidth measurement is in two parts relatively independent of each other. The first gives the RF spectrum profile, and the second calculates the frequency limits and they result in the Occupied bandwidth. While the first involves RF measurement instrumentation, the second is strictly a computational part related to measured trace.

Getting an equally-sampled RF power spectrum profile requires a Digital Spectrum Analyzer. In addition to the instrument’s usual requirements, a special attention must be paid to the analyzer’s span (bandwidth to be investigated).

This bandwidth must be large enough to contain all the power spectral components created by the transmitter. The frequency step, where the samples are picked, is directly dependent on the span’s value.

Δf= span/number of points displayed

The frequency resolution will determine the measurement accuracy. So for greater accuracy, less bandwidth will give better values because of the constant number of points that can be displayed. Taking into account the purpose of transmitter, an acceptable balance can be set. For channel-limited transmitters all the power spectral components can be found in main channel and a number of adjacent channels, upper and lower, from the main channel. The relation between these two requirements, number of channels and accuracy, is depicted by:

$$a(\%) \cong (2*k*n/N)*100,$$

where a is desired accuracy, in percentage units, n is the number of channels in span, including main channel, N is displayed number of points and k= (authorized bandwidth) /channel bandwidth.

For usual spectrum analyzers N≅500, k=0.8 (20/25) for 25kHz channel transmitters or k=0.9 (11.25/12.5) for 12.5kHz channel transmitters, so a ≅ n/2.5 (%) can estimate the expected precision for measurement.

All other requirements for spectrum analyzer are the same as they are for mask compliance determination.

The second part has computational requirements related to the trace's values processing.

The following operations must be performed over the trace's (x,y) points:

1. convert y value in dBm (or the analyzer's display y units) units power sample
2. convert y value in W units power sample,
3. add to total power every power sample and get total power value (W units for total power)
4. set low level (0.5%*total power)
5. detect x1-sample which pass low level (convert f1 integrals to sample summing)
6. convert (x1-1)-sample value in frequency units (the x-sample is already in occupied bandwidth),
7. store first frequency correspondent to (x1-1)-sample
8. set up level (99.5%*total power)
9. detect x2-sample which pass up level (convert f2 integrals to sample summing)
10. convert (x2)-sample value in frequency units (the x-sample is now out of occupied bandwidth),
11. store second frequency correspondent to (x2)-sample
12. read the frequency difference , this is ***Occupied Bandwidth***, and display the result.

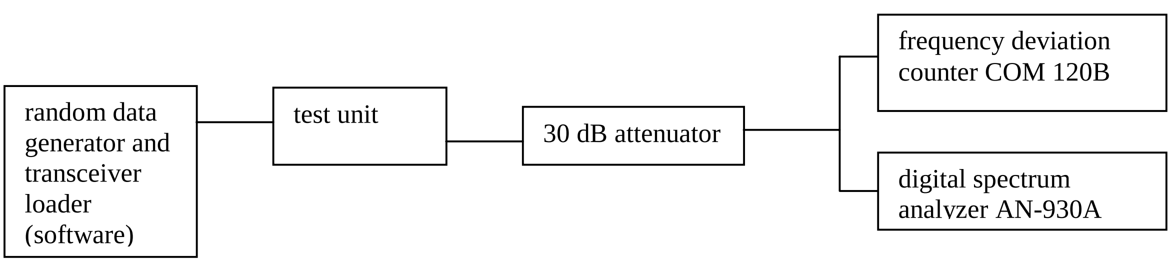
Standard calculation precision is all that is required. The main error factor being the y display resolution is covering calculation precision.

The absolute error for this measurement is -0/+2*)f. It is not possible to decrease span bandwidth under 2 channels bandwidth because this will affect the significance of result by cutting off the power's spectral distribution edges.

Dataradio's Measurement Set-Up

For the above requirements, the occupied bandwidth of a transmitter was measured using an IFR AN930 A spectrum analyzer having adequate macrofunction to perform computational part. The number of power spectrum samples (N) is 500. Because in test results frequency deviation was also a parameter, measurement instruments were completed with an IFR COM-120 B for frequency deviation determination.

The measurement set-up is:



The AN-930 A spectrum analyzer's parameters are adjusted as follow:
-total span is adjusted at 2.8*channel space this means 70 kHz for 25 kHz channel and 35 kHz for 12.5 kHz channel. This setting will result in frequency sample step (f) of 140 Hz for 25 kHz channel and 70 Hz for 12.5 kHz channel.
-RBW is set to 300 Hz, this is better than 1% of total span bandwidth.
-video filter is set to 1Khz;
-all other parameter of the instrument are automatically adjusted to obtain calibrated measurements (sweep time 4s).
-central frequency and reference level are adjusted to the unmodulated carrier frequency and level.

The AN 930 A spectrum analyzer's Occupied Bandwidth macrofunction input parameters are:
-central frequency, same as above, the unmodulated carrier frequency.
-channel spacing, 25 kHz or 12.5 kHz according to the signal,
-percentage of Occupied Bandwidth 99%.

The macro operations are:
-the trace is read;
-follow all the computational steps required.
Each sample is converted from dBm to mW and add to total power (tpow) variable. Then are computed the limits of 0.5% and 99.5% by using variable remaining percent (RemPer), and in same time are stored sample number where these two percentage meet. Then are assigned to the markers the correspondent frequencies of numbers.
- Occupied Bandwidth is then displayed as Delta mode marker (difference between markers).
-return to operational mode.

NOTE 1: The computational part could be performed on every device featured with data acquisition.
NOTE 2: An approximation of the occupied bandwidth calculation can be performed by measuring at the points at which the spectrum, measured with a spectrum analyzer of 300 Hz resolution bandwidth, is 25dB down relative to the unmodulated carrier reference level.

NAME OF TEST: Transmitter Occupied Bandwidth

INTEGRA Modem at 9600 bps

In Support of Emission Designator **9K30F1D**

RULE PART NUMBER: 2.201, 2.202, 2.1033 (c)(14), 2.1049(h), 2.1041, 90.209(b)(5), 90.210 (d)

MINIMUM STANDARD:
Mask D
Sidebands and Spurious [Rule 90.210 (d), P = 5 Watts]
Authorized Bandwidth = 11.25 kHz [Rule 90.209(b) (5)]
From Fo to 5.625 kHz, down 0 dB. Greater than 5.625 kHz to 12.5 kHz, down 7.27(f_d-2.88kHz) dB. Greater than 12.5 kHz, at least 50+10$\log_{10}$(P) or 70 dB, whichever is the lesser of the attenuation.

Attenuation = 0 dB at Fo to 5.625 kHz
Attenuation = 20 dB at 5.625 kHz and 70 dB at 12.5 kHz
Attenuation = 57 dB at > 12.5 kHz

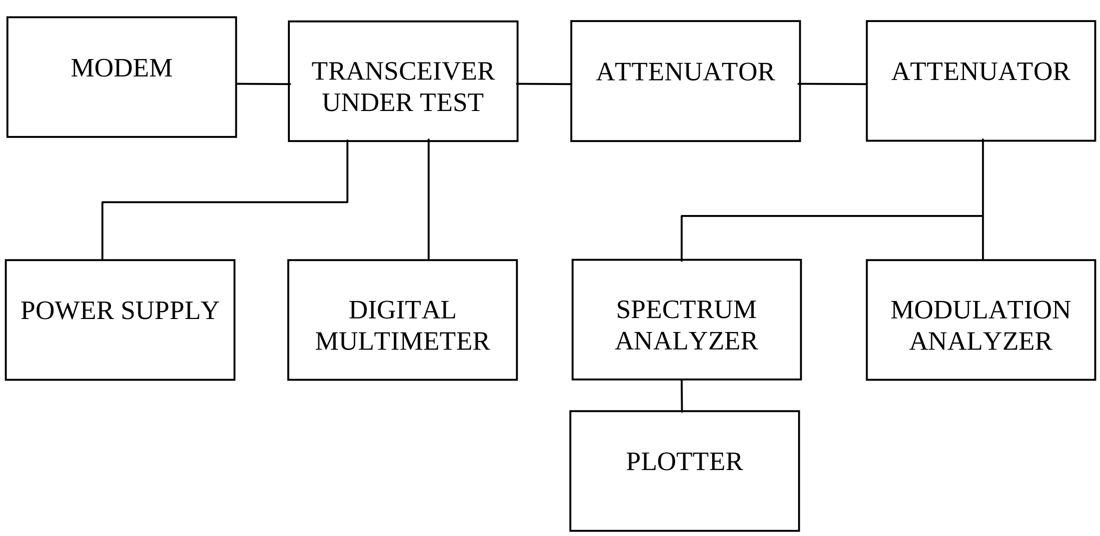
TEST RESULTS: Meets minimum standard (see data on the following pages)

TEST CONDITIONS: Standard Test Conditions, 25 C

TEST EQUIPMENT:
Attenuator, BIRD Model / 9715 / 50-A-MFN-06 / 6 dB / 50 Watt
Attenuator, BIRD Model / 9716 / 25-A-MFN-20 / 20 dB / 25 Watt
Digital Voltmeter, Fluke Model 8012A
DC Power Source, Model HP6284A
Modulation Analyzer, Model HP8901A
Spectrum Analyzer, Model HP8563E
Plotter, HP7470A

PERFORMED BY: Allen Frederick DATE: 1/29/99

TEST SET-UP:



NAME OF TEST: Transmitter Occupied Bandwidth (Continued)
INTEGRA Modem at 9600 bps
In Support of Emission Designator **9K30F1D**

MODULATION SOURCE DESCRIPTION:
The digital modulation type used in the INTEGRA is DRCMSK (Differential Raised Cosine Minimum Shift Keying). A modem using such type of modulation is divided into three main functional units in a CPLD chip:
Scrambler:
The scrambler converts the data stream to a new data stream more suitable for FM transmission.
-It randomizes the data to avoid predictable patterns: 00000000, 111111111, 01010101, 00110011, etc.
-It keeps the power spectrum more compact by avoiding sequences like 01010101…
The scrambler is made with a serial shift register and 2 exclusive OR gates which implement the polynomial form X^7+X^5-1. For the receiver side, a similar circuit performs the descrambling function to decode the received scrambled data.

Differential encoder:
After data is scrambled, we encode the data with a differential encoder. The differential encoder XOR's the current input bit with the previous bit. The differential encoder is used to make the modem insensitive to audio polarity inversion of the FM radio system.

Waveshape generator:
The waveshape generator converts the processed data bits (scrambled and differentially encoded for DRCMSK) to the DRCMSK audio signal. This audio signal is passed through a low-pass filter before modulating the RF transmitter.

TRANSMISSION PREAMBLE:
Each data transmission begins by sending a 15 millisecond preamble of sinewave (101010...). This is to synchronize the digital phase locked loop of the receiver modem.

TEST PATTERN GENERATOR:
A 30 s test pattern sequence is generated by the test software when the "test data" button is clicked. The highest resulting modulating frequency is (baud rate)/2 Hz. The following pseudo random test pattern was used to modulate the transmitter:

###ABCDEFGHIJKLMNOPQRSTUVWXYZabcdefghijklmnopqrstuvwxyz0123456789\r\n,

In this pattern ### is replaced by the number of replays, \r is a carriage return and \n is a linefeed. The data is fed to the RS232 interface IC and processed as described above. The async-to-sync conversion, scrambler and differential encoder make the ABCDE... pattern appear random over the air.

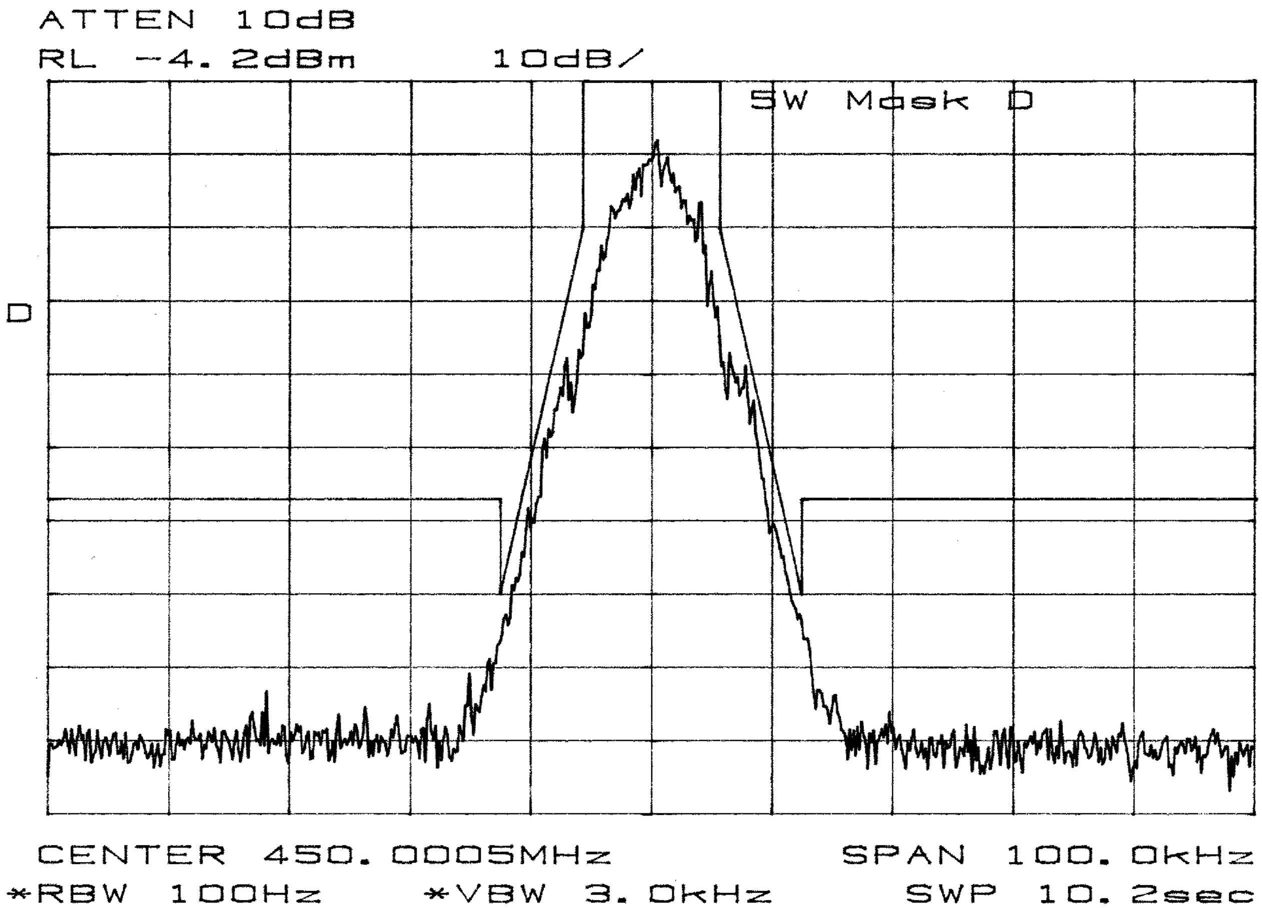
NECESSARY BANDWIDTH (Bn) CALCULATION

See page 13 for Emission Designator determination.

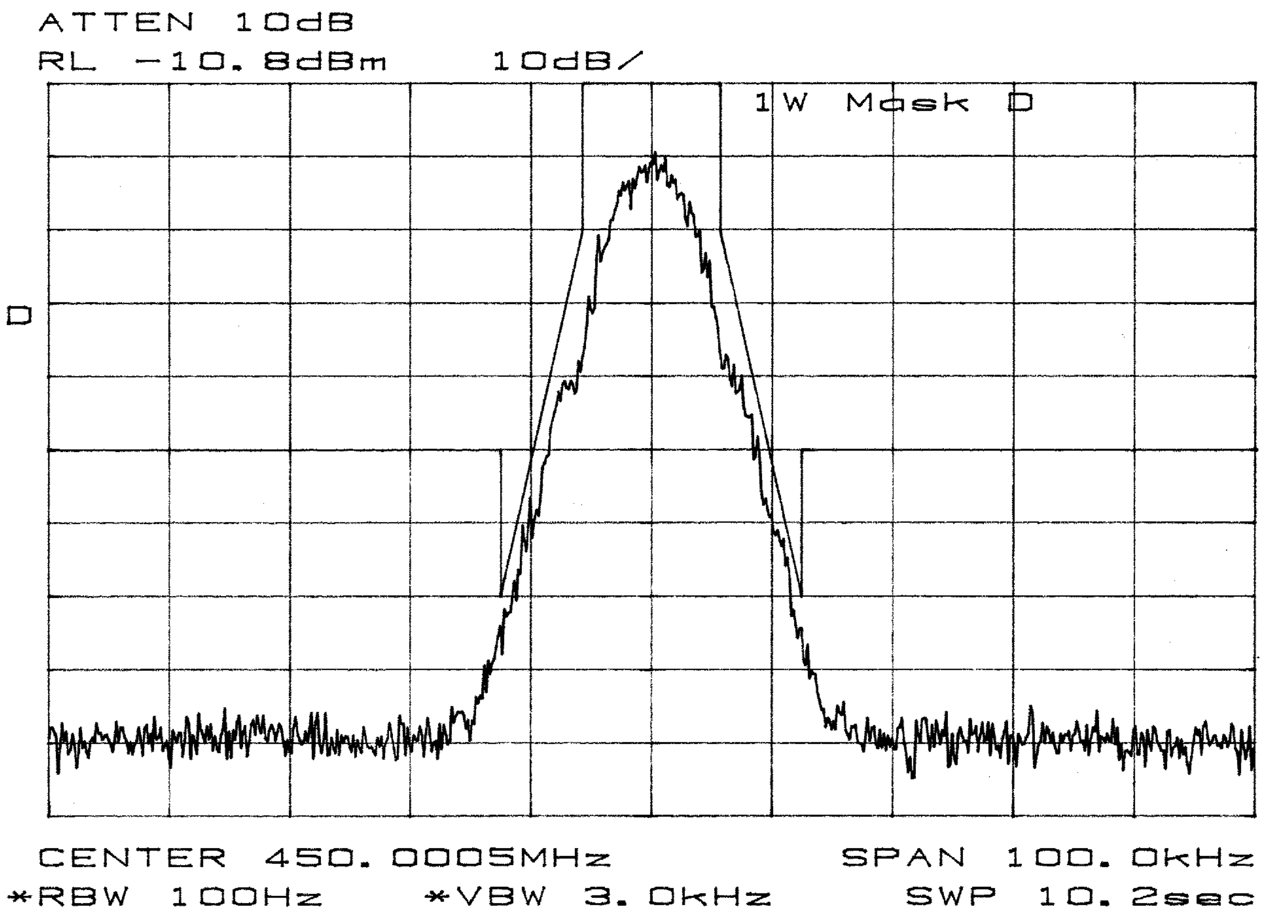
The corresponding emission designator prefix for necessary bandwidth = **9K30**

TEST DATA: Refer to the following graphs:

MASK: D,5W
SPECTRUM FOR EMISSION **9K30F1D**
OUTPUT POWER: 5 Watts
9600 bps
PEAK DEVIATION = 2500 Hz
SPAN = 100 kHz

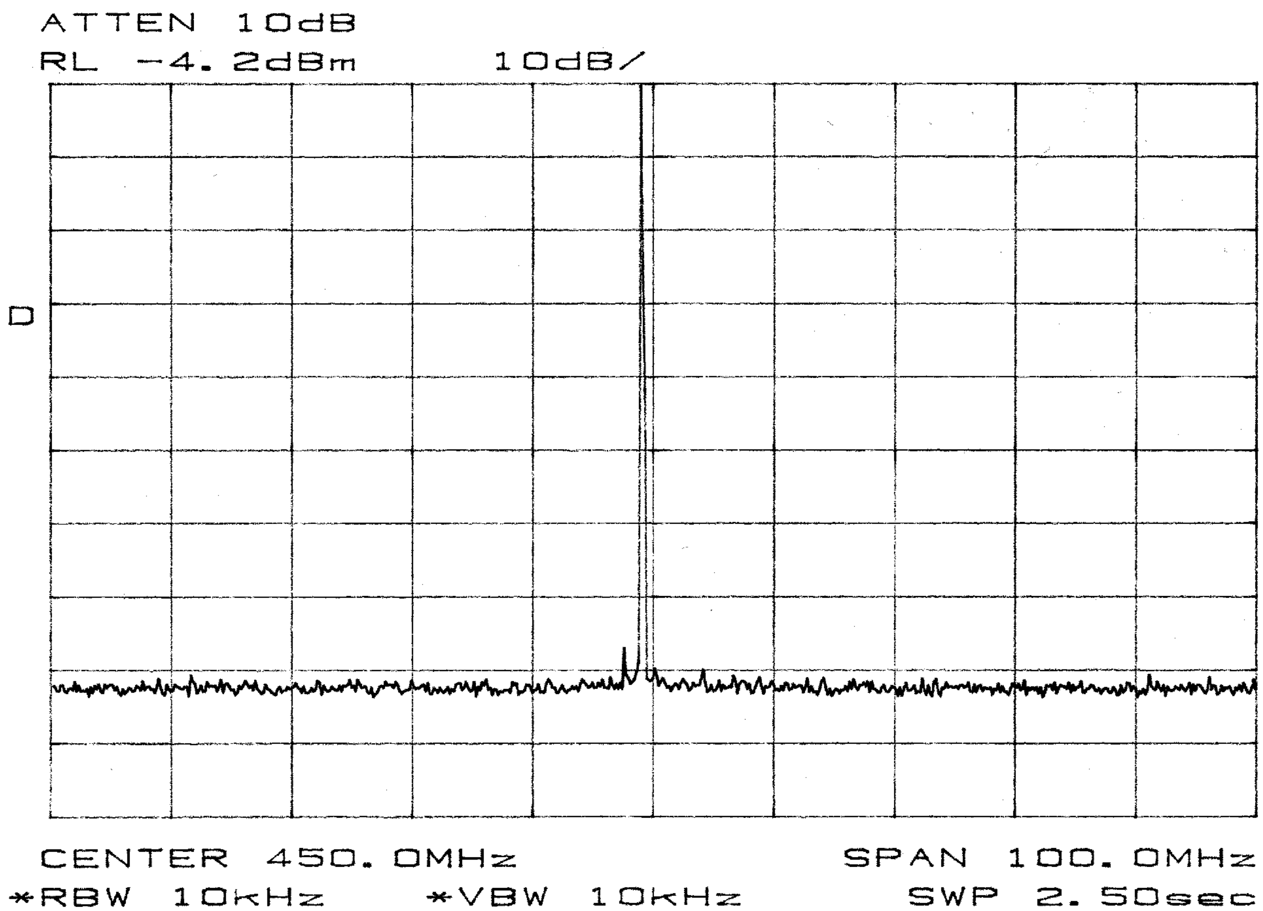


MASK: D,1W
SPECTRUM FOR EMISSION **9K30F1D**
OUTPUT POWER: 1 Watts
9600 bps
PEAK DEVIATION = 2500 Hz
SPAN = 100 kHz

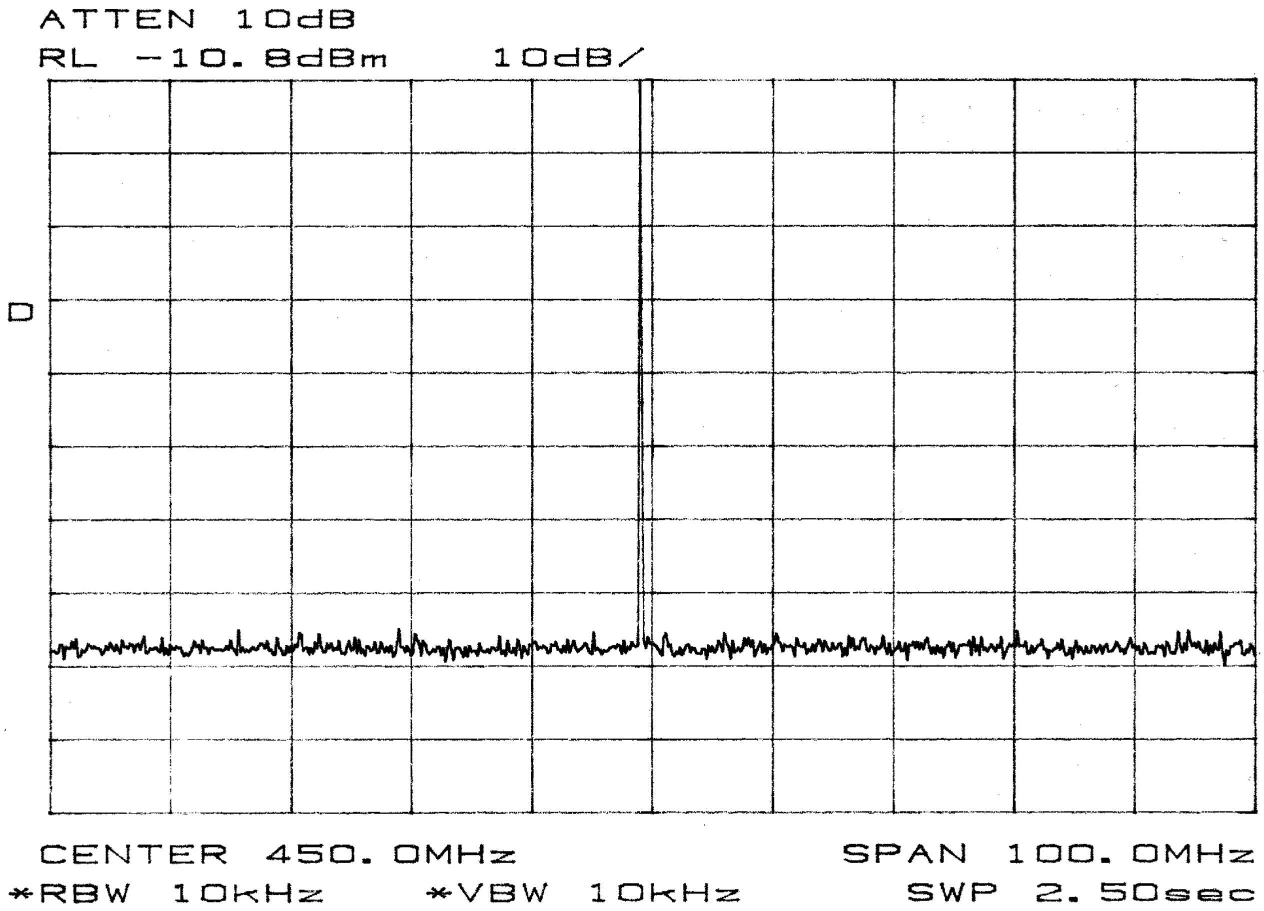


WIDE SPAN = 100 MHz

OUTPUT POWER: 5 Watts



WIDE SPAN = 100 MHz
OUTPUT POWER: 1 Watts



NAME OF TEST: Transmitter Occupied Bandwidth

INTEGRA Modem at 19.2 Kbps

In Support of Emission Designator **15K3F1D**

RULE PART NUMBER: 2.201, 2.202, 2.1033 (c)(14), 2.1049(h), 2.1041, 90.209(b)(5), 90.210 (b)

MINIMUM STANDARD:
Mask B
Sidebands and Spurious [Rule 90.210 (b), P = 5 Watts]
Authorized Bandwidth = 20 kHz [Rule 90.209(b) (5)]
From Fo to 50% of Authorized BW Removed from Fo, down 0 dB.
From 50% to 100% removed, at least 25 dB.
From 100% to 250% removed, at least 35 dB.
Greater than 250% remove, at least $43 + 10\log_{10}(P)$ dB.

Fo to 10 kHz Attenuation = 0 dB
10 kHz to 20 kHz, Attenuation = 25 dB minimum
20 kHz to 50 kHz, Attenuation = 35 dB minimum
> 50 kHz, Attenuation = 50 dB minimum (5 watts)
> 50 kHz, Attenuation = 43 dB minimum (1 watt)

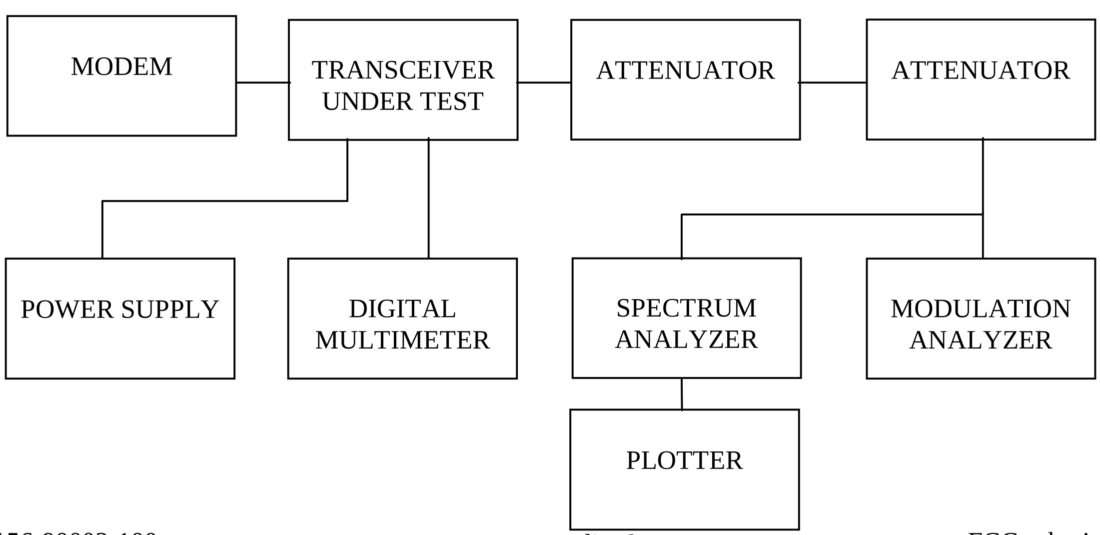
TEST RESULTS: Meets minimum standard (see data on the following pages)

TEST CONDITIONS: Standard Test Conditions, 25 C

TEST EQUIPMENT:
Attenuator, BIRD Model / 9715 / 50-A-MFN-06 / 6 dB / 50 Watt
Attenuator, BIRD Model / 9716 / 25-A-MFN-20 / 20 dB / 25 Watt
Digital Voltmeter, Fluke Model 8012A
DC Power Source, Model HP6284A
Modulation Analyzer, Model HP8901A
Spectrum Analyzer, Model HP8563E
Plotter, HP7470A

PERFORMED BY: Allen Frederick DATE: 1/29/99

TEST SET-UP:



NAME OF TEST: Transmitter Occupied Bandwidth (Continued)
INTEGRA Modem at 19200 bps
In Support of Emission Designator **15K3F1D**

MODULATION SOURCE DESCRIPTION:
The digital modulation type used in the INTEGRA is DRCMSK (Differential Raised Cosine Minimum Shift Keying). A modem using such type of modulation is divided into three main functional units in a CPLD chip:
Scrambler:
The scrambler converts the data stream to a new data stream more suitable for FM transmission.
-It randomizes the data to avoid predictable patterns: 00000000, 111111111, 01010101, 00110011, etc.
-It keeps the power spectrum more compact by avoiding sequences like 01010101…
The scrambler is made with a serial shift register and 2 exclusive OR gates which implement the polynomial form X^7+X^5-1. For the receiver side, a similar circuit performs the descrambling function to decode the received scrambled data.

Differential encoder:
After data is scrambled, we encode the data with a differential encoder. The differential encoder XOR's the current input bit with the previous bit. The differential encoder is used to make the modem insensitive to audio polarity inversion of the FM radio system.

Waveshape generator:
The waveshape generator converts the processed data bits (scrambled and differentially encoded for DRCMSK) to the DRCMSK audio signal. This audio signal is passed through a low-pass filter before modulating the RF transmitter.

TRANSMISSION PREAMBLE:
Each data transmission begins by sending a 15 millisecond preamble of sinewave (101010...). This is to synchronize the digital phase locked loop of the receiver modem.

TEST PATTERN GENERATOR:
A 30 s test pattern sequence is generated by the test software when the "test data" button is clicked. The highest resulting modulating frequency is (baud rate)/2 Hz. The following pseudo random test pattern was used to modulate the transmitter:

###ABCDEFGHIJKLMNOPQRSTUVWXYZabcdefghijklmnopqrstuvwxyz0123456789\r\n,

In this pattern ### is replaced by the number of replays, \r is a carriage return and \n is a linefeed. The data is fed to the RS232 interface IC and processed as described above. The async-to-sync conversion, scrambler and differential encoder make the ABCDE... pattern appear random over the air.

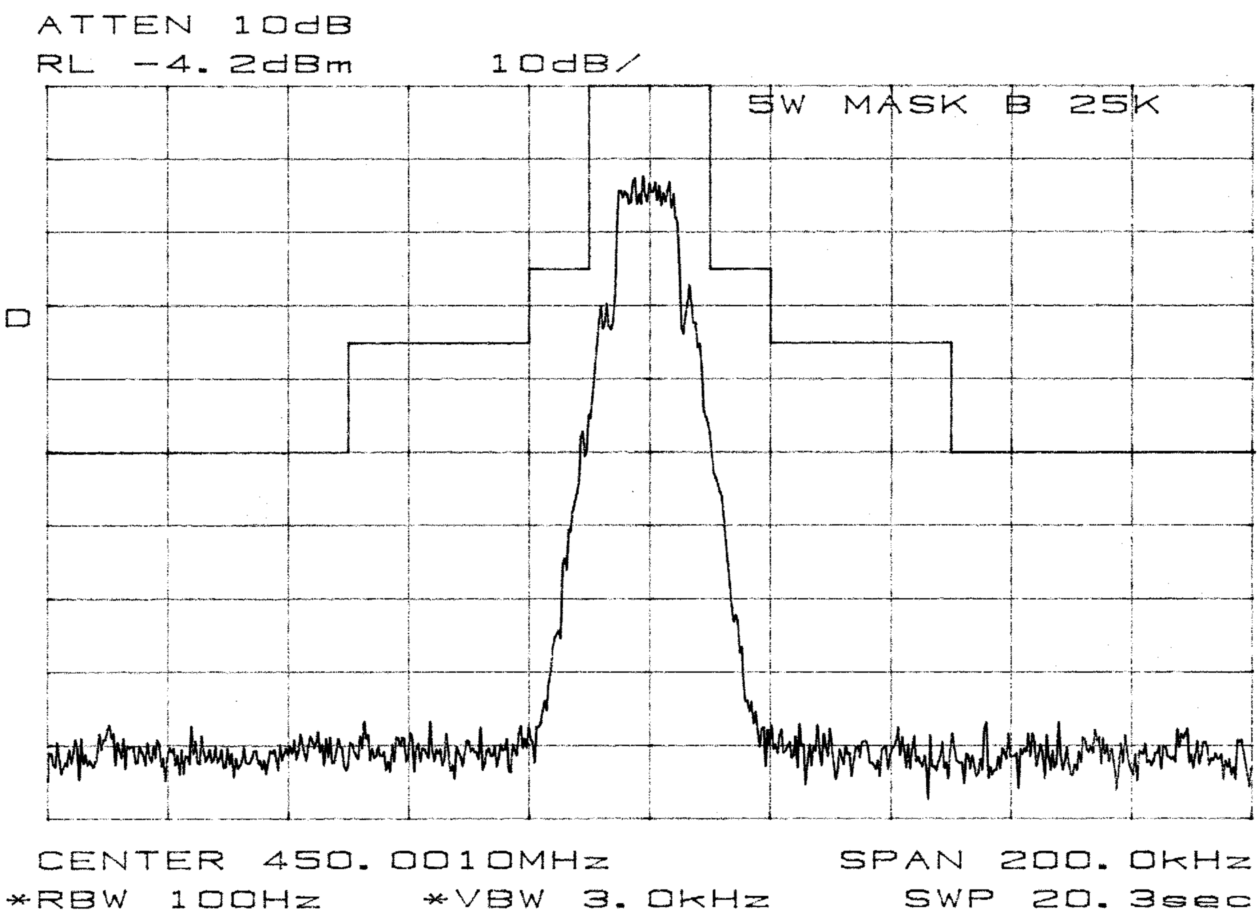
NECESSARY BANDWIDTH (Bn) CALCULATION

See page 13 for Emission Designator determination.

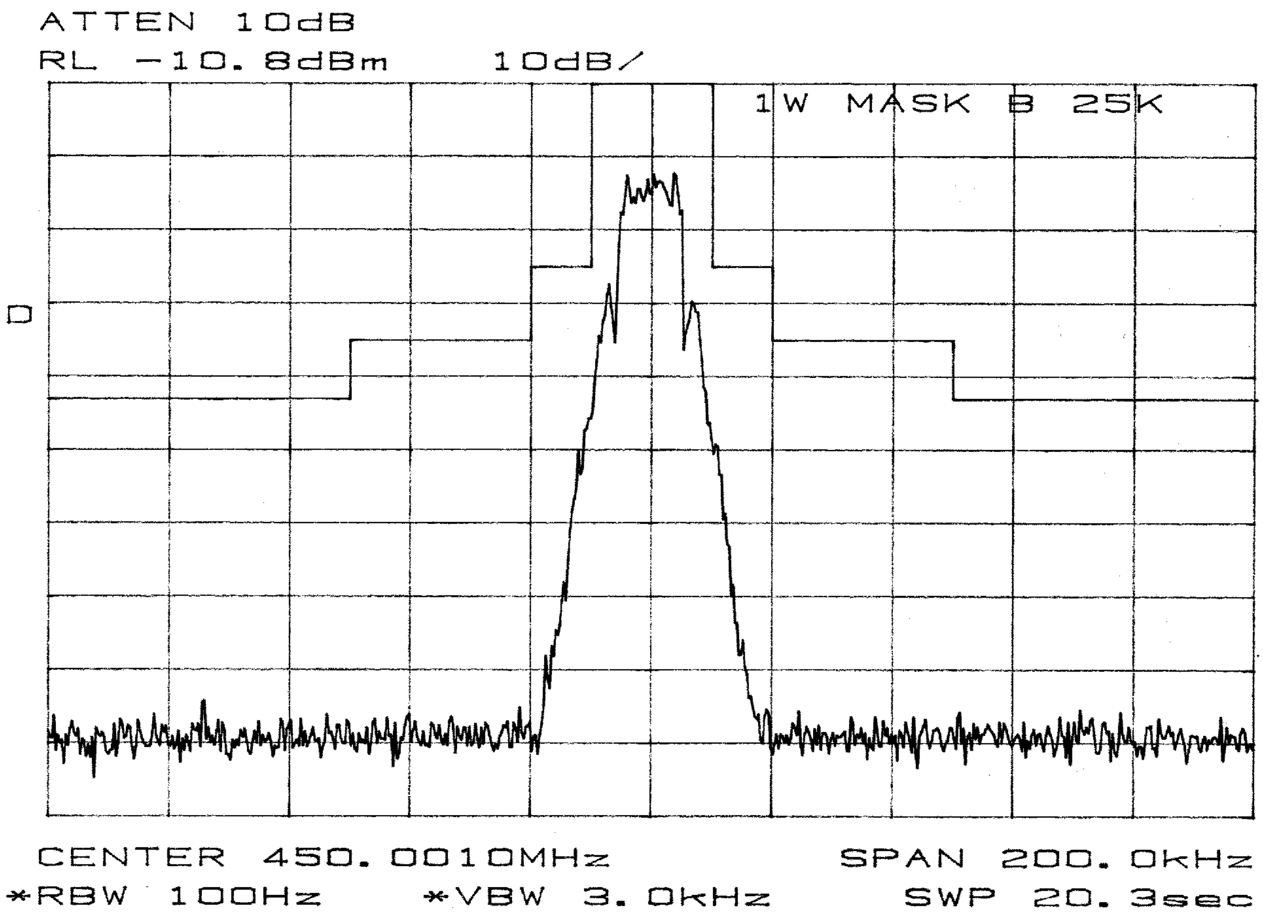
The corresponding emission designator prefix for necessary bandwidth = **15K3**

TEST DATA: Refer to the following graphs:

MASK: B,5W
SPECTRUM FOR EMISSION **15K3F1D**
OUTPUT POWER: 5 Watts
19200 bps
PEAK DEVIATION = 4000 Hz
SPAN = 200 kHz



MASK: B,1W
SPECTRUM FOR EMISSION **15K3F1D**
OUTPUT POWER: 1 Watts
19200 bps
PEAK DEVIATION = 4000 Hz
SPAN = 200 kHz



NAME OF TEST: Transmitter Spurious and Harmonic Outputs

RULE PART NUMBER: 2.1033 c(14), 2.1041, 2.1051, 90.210 (d)(3)

MINIMUM STANDARD: For 5 Watt; $50+10Log_{10}$(5 Watts) = -57 dBc
or -70 dBc whichever is the lesser attenuation.

TEST RESULTS: Meets minimum standard (see data on the following page)

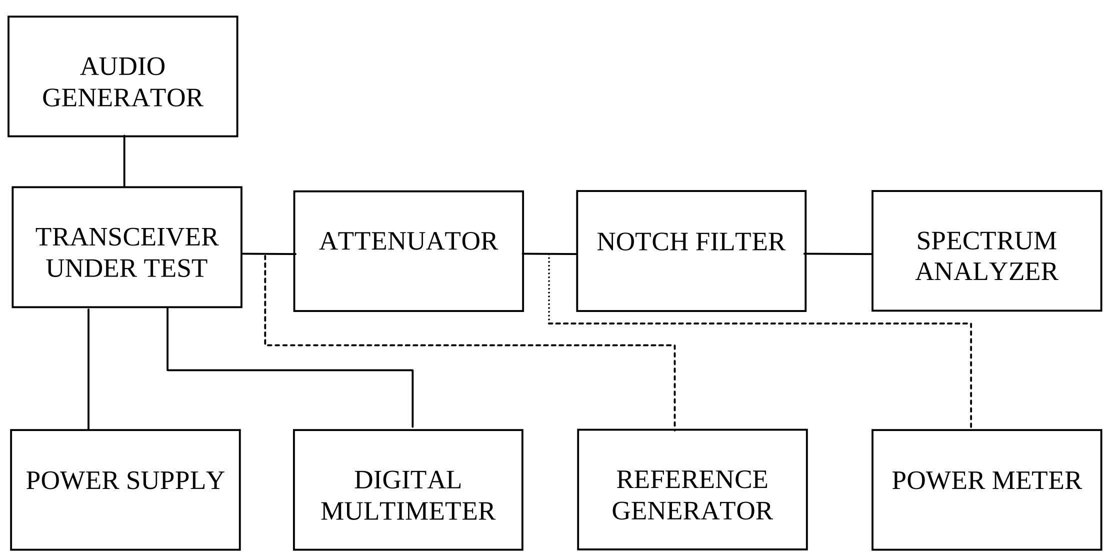
TEST CONDITIONS: Standard Test Conditions, 25 C
RF voltage measured at antenna terminals

TEST PROCEDURE: TIA/EIA - 603, 2.2.13

TEST EQUIPMENT:
Attenuator, BIRD Model / 9715 / 50-A-MFN-06 / 6 dB / 50 Watt
Attenuator, BIRD Model / 9716 / 25-A-MFN-20 / 20 dB / 25 Watt
Digital Voltmeter, Fluke Model 8012A
DC Power Source, Model HP6284A
Modulation Analyzer, Model HP8901A
Spectrum Analyzer, Model HP8563E
Plotter, HP7470A
Reference Generator, Model HP83732B
Power Meter, Model HP436A
Audio Generator, Model HP8903B

PERFORMED BY: ______________________________ Date:1/28/99
Allen Frederick

TEST SET-UP:



NAME OF TEST: Transmitter Spurious and Harmonic Outputs (Continued)

MEASUREMENT PROCEDURE:

1. The transmitter carrier output frequency is 403.000, 450.000 and 512.000 MHz. The reference oscillator frequency is 17.5000 MHz.

2. After carrier reference was established on spectrum analyzer, the notch filter was adjusted to null the carrier Fc to extend the range of the spectrum analyzer for harmonic measurements.

3. At each spurious frequency, Generator substitution was used to establish the true spurious level.

4. The spectrum was scanned to the 10th harmonic.

TEST DATA:

Tuned Frequency	403 MHz		Tuned Frequency	403 MHz	
Power	1 Watts		Power	5 Watts	
	30.0 dBm			37.0 dBm	
Minimum Specification	50.0 dBm		Minimum Specification	57.0 dBm	
Worse Case	68.5 dBc		Worse Case	69.5 dBc	
Spurious Frequency (MHz)	Relation to Carrier	Relative to Carrier (dBc)	Spurious Frequency (MHz)	Relation to Carrier	Relative to Carrier (dBc)
806	2 fo	76.0	806	2 fo	69.5
1209	3 fo	91.5	1209	3 fo	75.5
1612	4 fo	68.5	1612	4 fo	73.0
2015	5 fo	96.0	2015	5 fo	102.0
2418	6 fo	95.0	2418	6 fo	99.0
2821	7 fo	93.5	2821	7 fo	96.5
3224	8 fo	94.5	3224	8 fo	98.0
3627	9 fo	85.0	3627	9 fo	90.0
4030	10 fo	95.5	4030	10 fo	96.5

NAME OF TEST: Transmitter Spurious and Harmonic Outputs (Continued)

Tuned Frequency	450 MHz		Tuned Frequency	450 MHz	
Power	1 Watts		Power	5 Watts	
	30.0 dBm			37.0 dBm	
Minimum Specification	50.0 dBm		Minimum Specification	57.0 dBm	
Worse Case	72.5 dBc		Worse Case	76.5 dBc	
Spurious Frequency (MHz)	Relation to Carrier	Relative to Carrier (dBc)	Spurious Frequency (MHz)	Relation to Carrier	Relative to Carrier (dBc)
900	2 fo	78.5	900	2 fo	86.0
1303	3 fo	84.5	1303	3 fo	89.5
1706	4 fo	82.0	1706	4 fo	89.0
2109	5 fo	84.5	2109	5 fo	88.5
2512	6 fo	105.5	2512	6 fo	114.0
2915	7 fo	84.0	2915	7 fo	92.0
3318	8 fo	72.5	3318	8 fo	76.5
3721	9 fo	88.5	3721	9 fo	98.5
4124	10 fo	97.0	4124	10 fo	101.0

Tuned Frequency	512 MHz		Tuned Frequency	512 MHz	
Power	1 Watts		Power	5 Watts	
	30.0 dBm			37.0 dBm	
Minimum Specification	50.0 dBm		Minimum Specification	57.0 dBm	
Worse Case	67.5 dBc		Worse Case	72.5 dBc	
Spurious Frequency (MHz)	Relation to Carrier	Relative to Carrier (dBc)	Spurious Frequency (MHz)	Relation to Carrier	Relative to Carrier (dBc)
1024	2 fo	83.0	1024	2 fo	78.0
1427	3 fo	84.0	1427	3 fo	79.0
1830	4 fo	104.5	1830	4 fo	87.5
2233	5 fo	67.5	2233	5 fo	72.5
2636	6 fo	87.5	2636	6 fo	94.5
3039	7 fo	83.0	3039	7 fo	85.5
3442	8 fo	106.0	3442	8 fo	113.0
3845	9 fo	92.5	3845	9 fo	86.0
4248	10 fo	104.0	4248	10 fo	108.0

NAME OF TEST: Field Strength of Spurious Radiation

RULE PART NUMBER: 2.1033 c(14), 2.1041, 2.1053, 90.210 (d)(3)

MINIMUM STANDARD: For 5 Watts; $50+10\text{Log}_{10}(5) = -57$ dBc

TEST RESULTS: Meets minimum standard (see data on the following page)

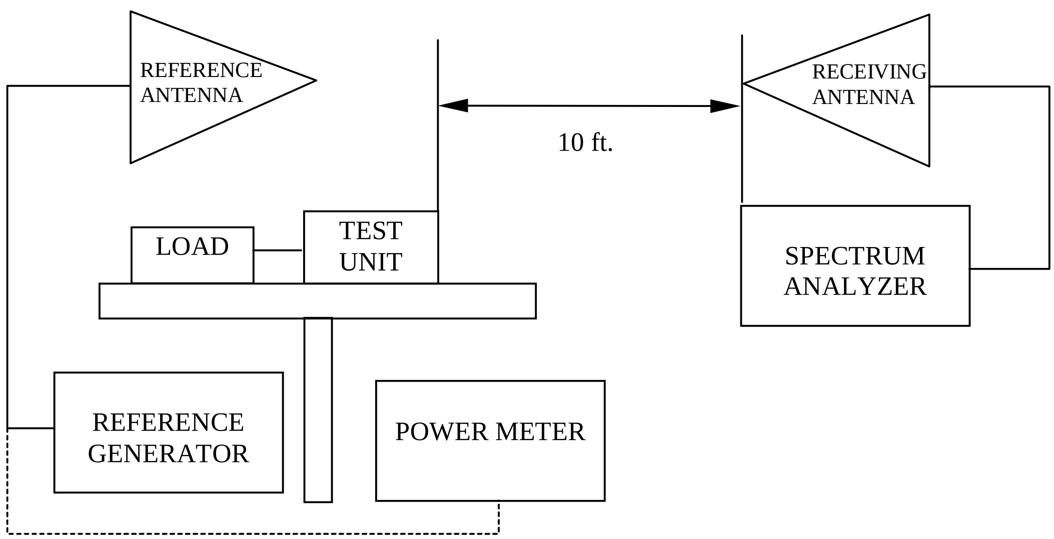
TEST CONDITIONS: Standard Test Conditions, 25 C

TEST PROCEDURE: TIA/EIA - 603, 2.2.12

Test Equipment:
Dipole Antenna Kit, Electro-Mechanics Model 3121C
Load, Tenuline Model 8340-200 (20 dB)
Spectrum Analyzer, HP 8563E
Reference Generator, HP83732A
Power Meter, HP437A

MEASUREMENT PROCEDURE: Radiated spurious attenuation was measured according to TIA/EIA Standard 603 Section 2.2.12

TEST SET-UP:



PERFORMED BY: Allen Frederick DATE: 4/5/99

Freqency:	450 MHz	Minimum Spec =	50.0	dBc
Power:	1 Watt=30.0dBm	Worse Case =	52.8	dBc

Spurious Frequency (MHz)	Polarization (Horz/Vert)	Spurious Level (dBm)	Substitution Generator (dBm)	Cable Loss (dB)	Antenna Gain (dBd)	Circular Polarization Correction (dB)	Spurious Attenuation dBc
900	H	-54.7	-19.0	5.67	-0.10	0.0	-54.8
	V	-55.0	-17.0	5.67	-0.10	0.0	-52.8
1350	H	-64.8	-21.0	6.50	1.20	3.0	-59.3
	V	-62.8	-20.0	6.50	1.20	3.0	-58.3
1800	H	-78.2	-32.0	7.67	1.20	3.0	-71.5
	V	-75.5	-30.0	7.67	1.20	3.0	-69.5
2250	H	-76.2	-29.0	8.30	1.20	3.0	-69.1
	V	-74.8	-24.0	8.30	1.20	3.0	-64.1
2700	H	-85.7	-35.0	8.83	1.20	3.0	-75.6
	V	-82.7	-32.0	8.83	1.20	3.0	-72.6
3150	H	-80.7	-28.0	9.30	1.20	3.0	-69.1
	V	-78.8	-25.0	9.30	1.20	3.0	-66.1
3600	H	-90.2	-28.0	10.67	1.20	3.0	-70.5
	V	-87.8	-30.0	10.67	1.20	3.0	-72.5
4050	H	-95.0	-36.0	11.67	1.20	3.0	-79.5
	V	-90.7	-31.0	11.67	1.20	3.0	-74.5
4500	H	-93.8	-33.0	11.67	1.20	3.0	-76.5
	V	-92.0	-32.0	11.67	1.20	3.0	-75.5

Freqency:	450 MHz	Minimum Spec =	57.0	dBc
Power:	5 Watts=37.0dBm	Worse Case =	60.3	dBc

Spurious Frequency (MHz)	Polarization (Horz/Vert)	Spurious Level (dBm)	Substitution Generator (dBm)	Cable Loss (dB)	Antenna Gain (dBd)	Circular Polarization Correction (dB)	Spurious Attenuation dBc
900	H	-53.2	-18.0	5.67	-0.10	0.0	-60.8
	V	-57.0	-18.0	5.67	-0.10	0.0	-60.8
1350	H	-59.7	-17.0	6.50	1.20	3.0	-62.3
	V	-56.8	-15.0	6.50	1.20	3.0	-60.3
1800	H	-82.2	-37.0	7.67	1.20	3.0	-83.5
	V	-78.8	-33.6	7.67	1.20	3.0	-80.1
2250	H	-73.3	-26.0	8.30	1.20	3.0	-73.1
	V	-70.0	-21.0	8.30	1.20	3.0	-68.1
2700	H	-80.2	-29.0	8.83	1.20	3.0	-76.6
	V	-76.0	-25.0	8.83	1.20	3.0	-72.6
3150	H	-81.5	-30.0	9.30	1.20	3.0	-78.1
	V	-75.7	-23.0	9.30	1.20	3.0	-71.1
3600	H	-83.7	-28.0	10.67	1.20	3.0	-77.5
	V	-81.7	-25.0	10.67	1.20	3.0	-74.5
4050	H	-89.8	-32.0	11.67	1.20	3.0	-82.5
	V	-84.5	-25.0	11.67	1.20	3.0	-75.5
4500	H	-92.7	-32.0	11.67	1.20	3.0	-82.5
	V	-90.5	-30.0	11.67	1.20	3.0	-80.5

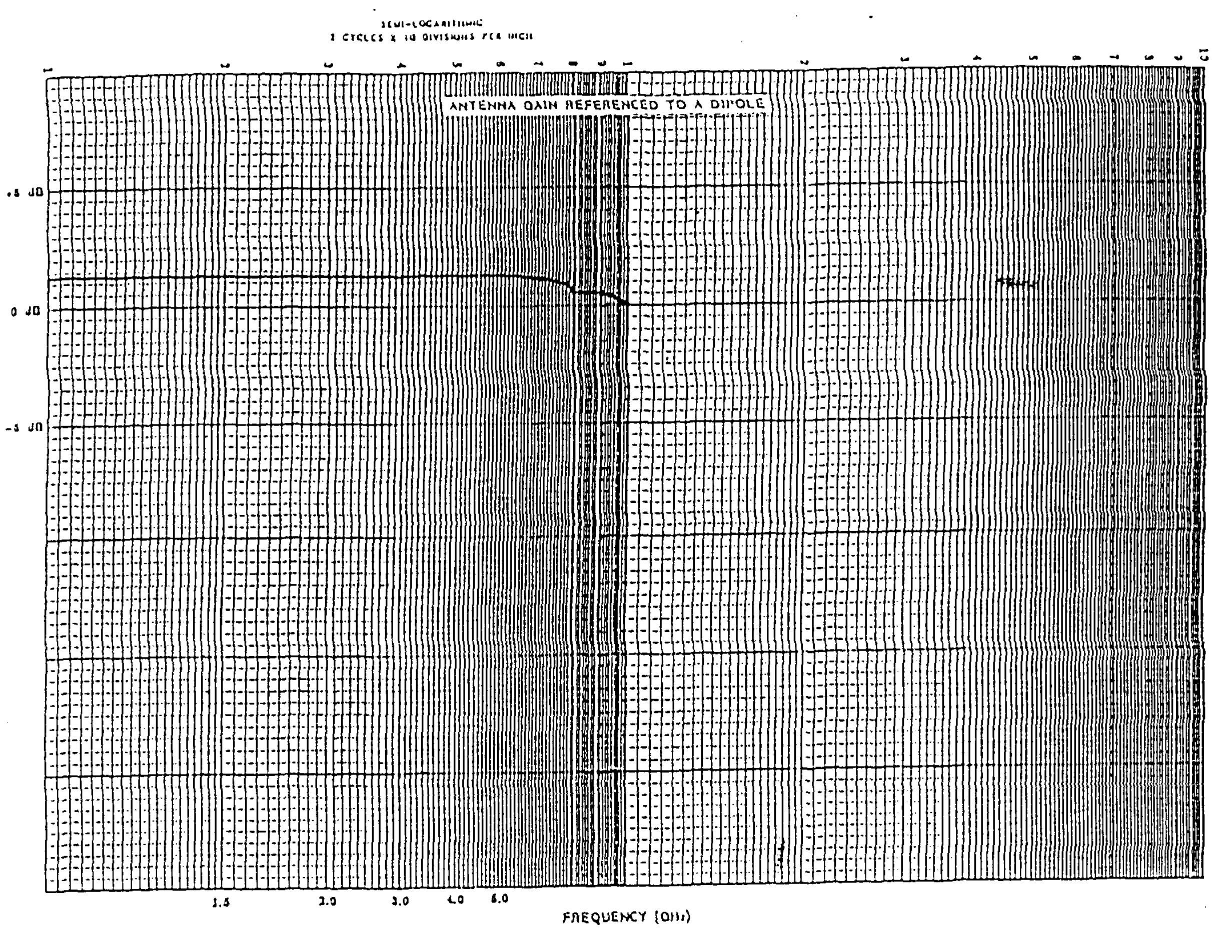
CALCULATIONS FOR FIELD STRENGTH OF SPURIOUS RADIATION TESTS:

The transmitter carrier frequency was 450.000 MHz. The reference oscillator frequency of all the transceivers used is 17.50 MHz. The output of the transceiver was searched from 17.50 MHz to the tenth harmonic of the carrier frequencies. The tests were conducted with the transceiver and modem inside of the enclosure.

Because the antennas used for the measurements recorded above 1 GHz were not flat in gain and differed from a dipole, the generator output was corrected for gain at each spurious frequency. The cable loss in the measurements is the loss in the cable between the signal generator and the substitution antenna. An additional 3 dB correction was also made to the spurious responses measured above 1 GHz to correct for the 3 dB polarization loss in the reference path.

EXAMPLE:
At 900 MHz (450 MHz tuned), 5 Watts and horizontal polarization.

r = Substitution Gen - Cable Loss	-18.0 – 5.67	= -23.67
R - Reference Generator (dBm)	-23.67	
A - Antenna Gain (dB)	+-0.10	
P - Polarization Correction Factor (dB)	0.0	
R' (Corrected Reference (dBm)) = R + A - P	= -23.67 + -.1 - 0.0	= **-23.77 dBm**
Po - Radiated Carrier Power (dBm)	5 Watts = 37 dBm	
Radiated Spurious Emission (dBc) = Po - R'	= -23.77 - (+37)	= **-60.77 dBc**



ANTENNA GAIN GRAPH OF SUBSTITUTION ANTENNA
REFERENCED TO A DIPOLE

NAME OF TEST: Frequency Stability

-with Variation in Ambient Temperature

RULE PART NUMBER: 2.1055 (a)(1), 90.213 (a) (7)

MINIMUM STANDARD: Shall not exceed ± 0.000150% from test frequency, or 1.50 ppm

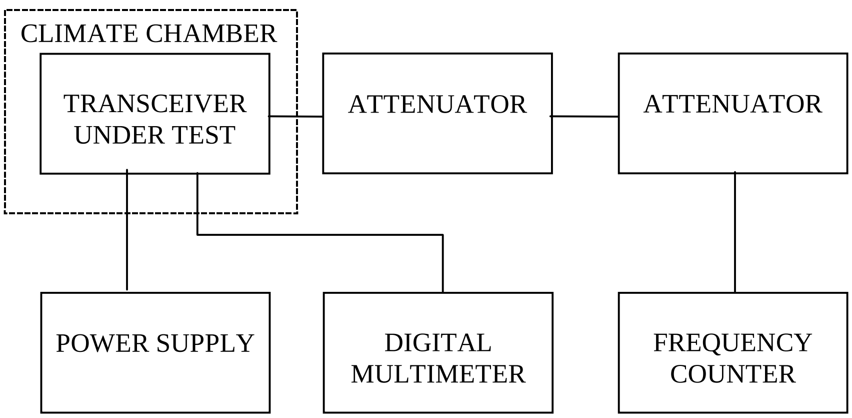
TEST RESULTS: Meets minimum standard, see data on following page

TEST CONDITIONS: Standard Test Conditions, 25 C

TEST EQUIPMENT:
Attenuator, BIRD Model / 9715 / 50-A-MFN-06 / 6 dB / 50 Watt
Attenuator, BIRD Model / 9716 / 25-A-MFN-20 / 20 dB / 25 Watt
Frequency Counter, Fluke Model 1920A
Digital Voltmeter, Fluke Model 8012A
DC Power Source, Model HP6284A
Climate Chamber, TempGard III, Tenney Jr.

PERFORMED BY: Allen Frederick DATE: 2/8/99

TEST SET-UP:



(Test data on next page)

NAME OF TEST: Frequency Stability with Variation in Ambient Temperature (Continued)

Frequency Reference: 450000000 Hz
Tolerance Requirement: 1.5 ppm
Highest Variation (ppm): 0.716 ppm

TEMP ° C	FREQUENCY MHz	FREQ DELTA Hz	ppm from assigned frequency
-30	449999678	-322	0.716
-20	449999794	-206	0.458
-10	449999727	-273	0.607
0	449999794	-206	0.458
10	449999907	-93	0.207
20	449999955	-45	0.100
30	450000156	156	0.347
40	450000039	39	0.087
50	449999863	-137	0.304
60	449999863	-137	0.304

NAME OF TEST: Frequency Stability
-with Variation in Supply Voltage

RULE PART NUMBER: 2.1055 (d)

MINIMUM STANDARD: Shall not exceed ± 0.000150% from test frequency, 1.50 ppm for ±15% change in supply voltage

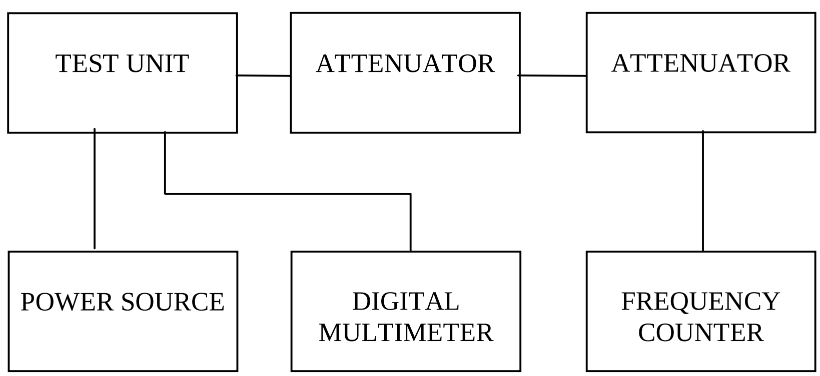
TEST RESULTS: Meets minimum standard, see data on following page

TEST CONDITIONS: Standard Test Conditions, 25 C

TEST EQUIPMENT:
Attenuator, BIRD Model / 9715 / 50-A-MFN-06 / 6 dB / 50 Watt
Attenuator, BIRD Model / 9716 / 25-A-MFN-20 / 20 dB / 25 Watt
Frequency Counter, Fluke Model 1920A
Digital Voltmeter, Fluke Model 8012A
DC Power Source, Model HP6284A

PERFORMED BY: ______________________ DATE: 2/8/99
Allen Frederick

TEST SET-UP:



(Test data on next page)

NAME OF TEST: Frequency Stability with Variation in Supply Voltage (Continued)

MEASUREMENTS TAKEN:

1.5 ppm Reference Oscillator

Frequency Reference Set at 25° C: 450.00001 MHz
Tolerance Requirement: 0.00015 %
Highest Variation (%): 0.00000000 %
Highest Variation (ppm): 0.000 ppm

SUPPLY VDC	FREQUENCY MHz	DELT FREQ % of assigned f	SPEC LIMIT % of assigned f	ppm from assigned frequency
10	450.00001	0.00000000	0.00015	0.000
13	**450.00001**	0.00000000	0.00015	0.000
16	450.00001	0.00000000	0.00015	0.000

NAME OF TEST: Transient Frequency Behavior

RULE PART NUMBER: 90.214

TEST CONDITIONS: The transient test was performed with the transmitter transmitting an unmodulated carrier tone. Also supplied is a transient test which was conducted with the INTEGRA modem modulating the transmitter at 4 kHz deviation. Also supplied is a transient test which was conducted with the INTEGRA modem modulating the transmitter at 2.5 kHz deviation.

MINIMUM STANDARD: **12.5 kHz channel** (used worst case numbers from 403 to 512 MHz)
25 kHz channel (used worst case numbers from 403 to 512 MHz)

TIME INTERVAL	MAXIMUM FREQUENCY DIFFERENCE (kHz)		TIME (mS)
	12.5KHz CH	25KHz CH	
T1	+/- 12.5	+/- 25	5
T2	+/- 6.25	+/- 12.5	20
T3	+/- 12.5	+/- 25	5

TEST RESULTS: Meets minimum standards, see data on following pages

TEST CONDITIONS: RF Power Level = 5 Watts
Standard Test Conditions, 25 C

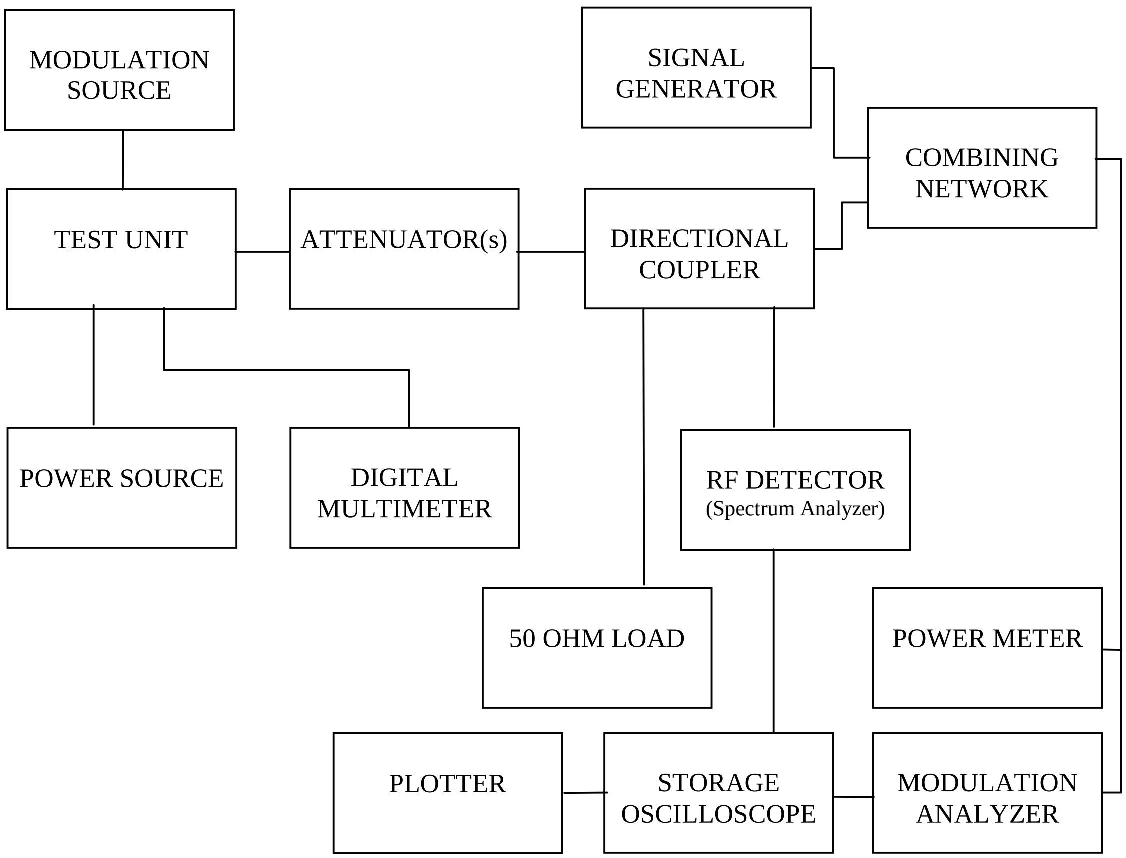
TEST PROCEDURE: TIA/EIA - 603, 2.2.19

TEST EQUIPMENT: Attenuator, BIRD Model / 9716 / 25-A-MFN-20 / 20 dB / 25 Watt
Digital Voltmeter, Fluke Model 8012A
DC Power Source, Model HP6284A
Modulation Analyzer, Model HP8901A
RF Detector (Spectrum Analyzer), Model HP8563E
Plotter, Model HP2671G
Reference Generator, Fluke Model 6071A
Power Meter, Model HP436A
Power Combiner, Model MCL ZFSC-4-1
Oscilloscope, Model HP54503A
Directional Coupler, Model HP778D

PERFORMED BY: Allen Frederick ________________________________ Date:2/2/99
Allen Frederick

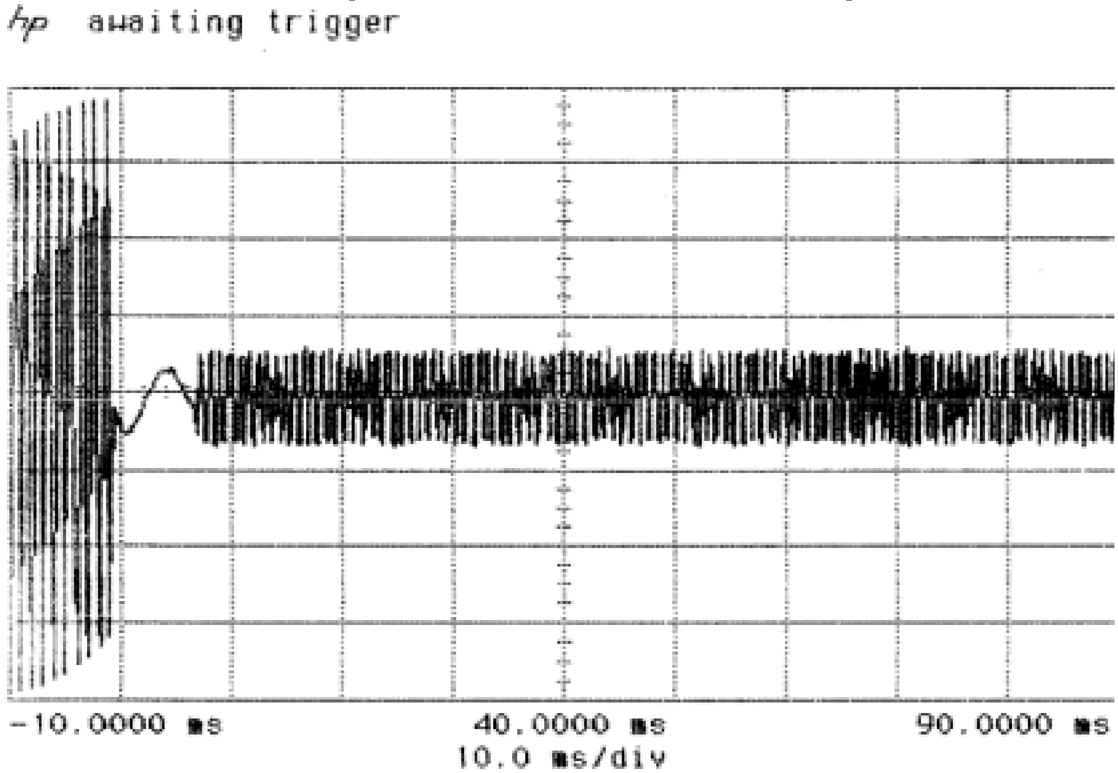
NAME OF TEST: Transient Frequency Behavior (Continued)

TEST SET-UP:

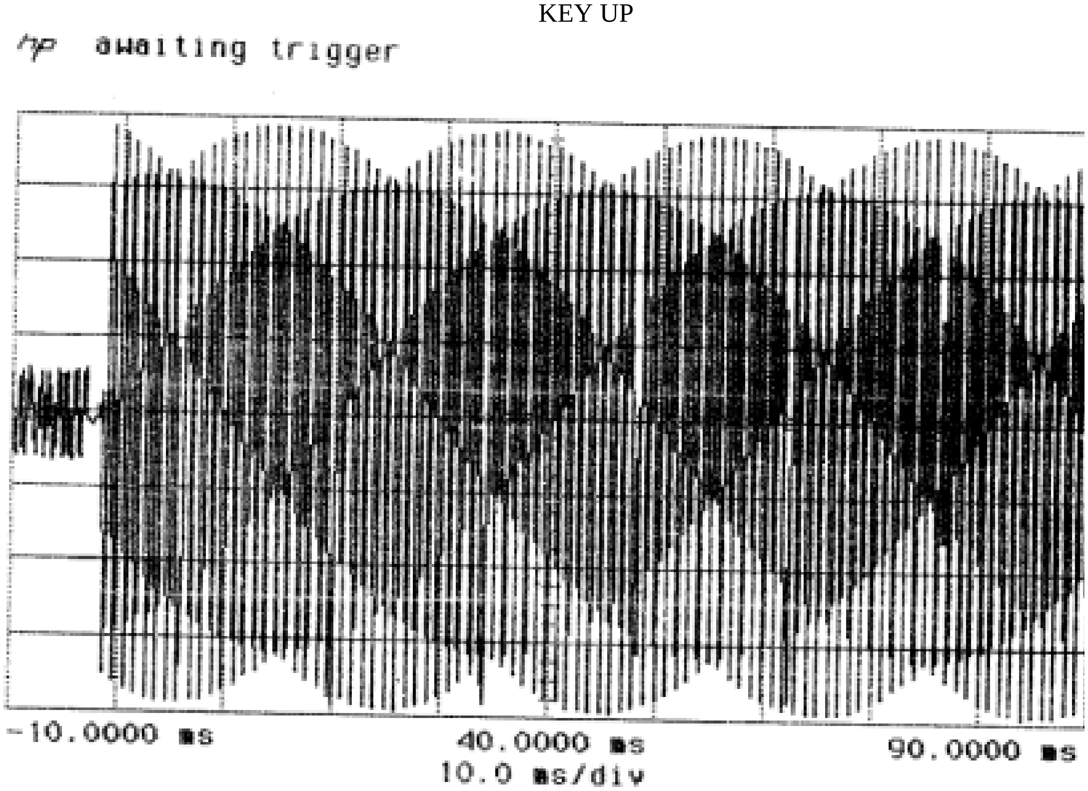


TRANSIENT FREQUENCY RESPONSE
TRANSCEIVER MODULATED BY INTEGRA MODEM 4 kHz DEVIATION

This corresponds to the INTEGRA modem set to 19.2 Kbps.

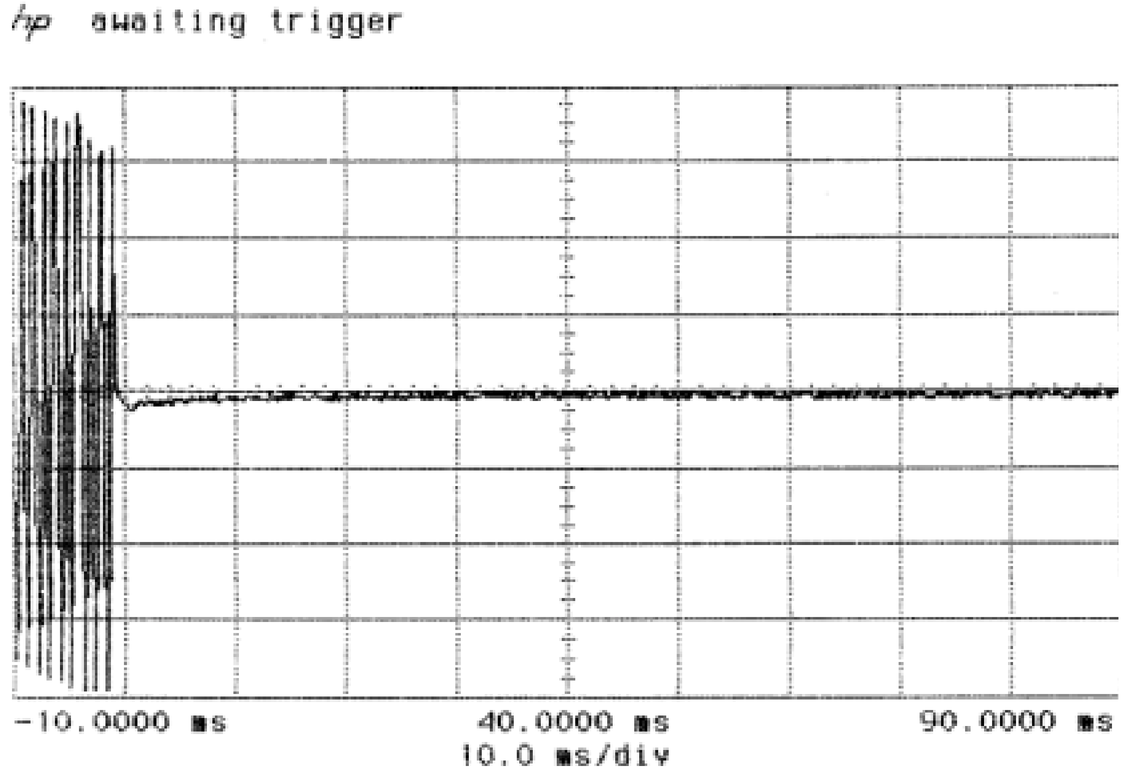


KEY UP

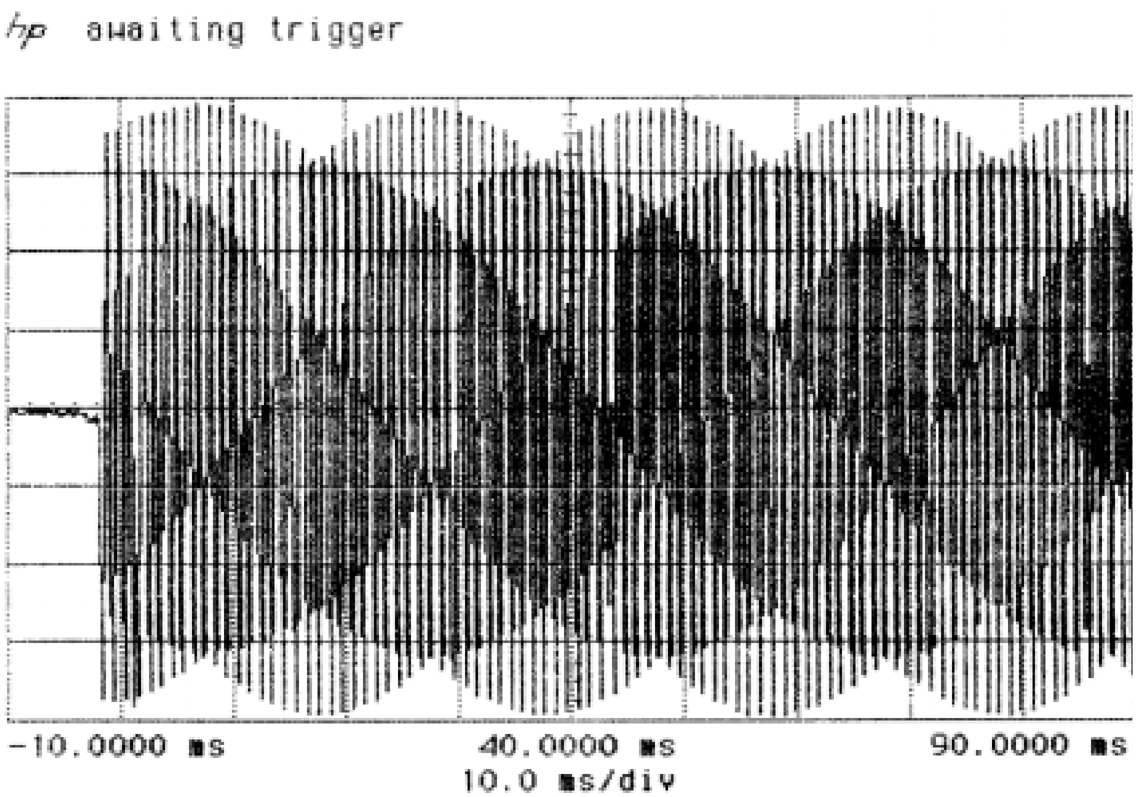


KEY DOWN

TRANSIENT FREQUENCY RESPONSE
TRANSCEIVER WITH UNMODULATED CARRIER

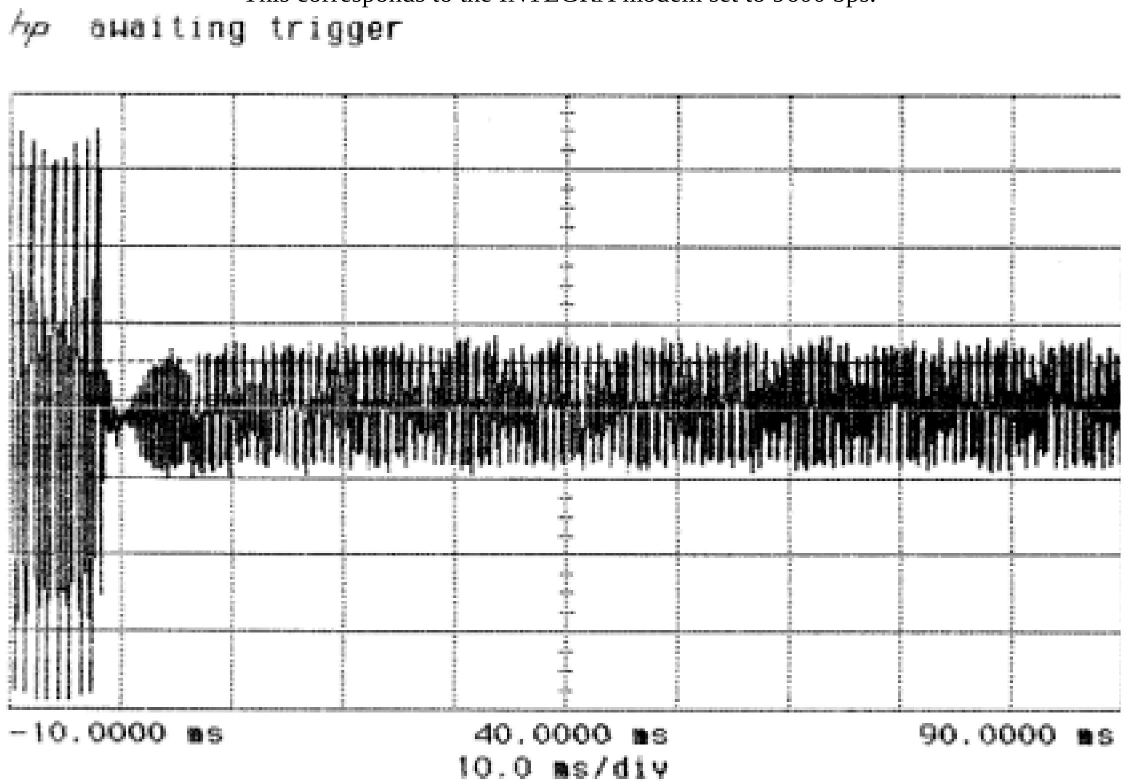


KEY UP

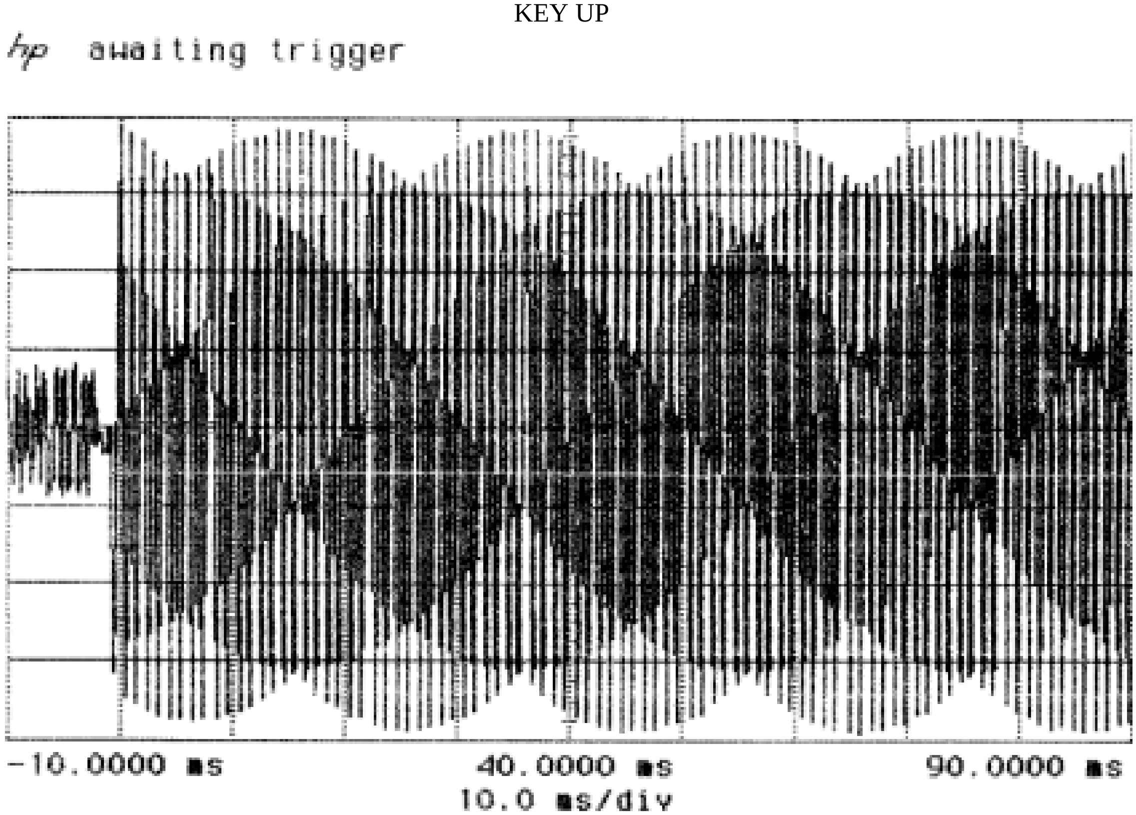


KEY DOWN
TRANSIENT FREQUENCY RESPONSE

TRANSCEIVER MODULATED BY INTEGRA MODEM
This corresponds to the INTEGRA modem set to 9600 bps.



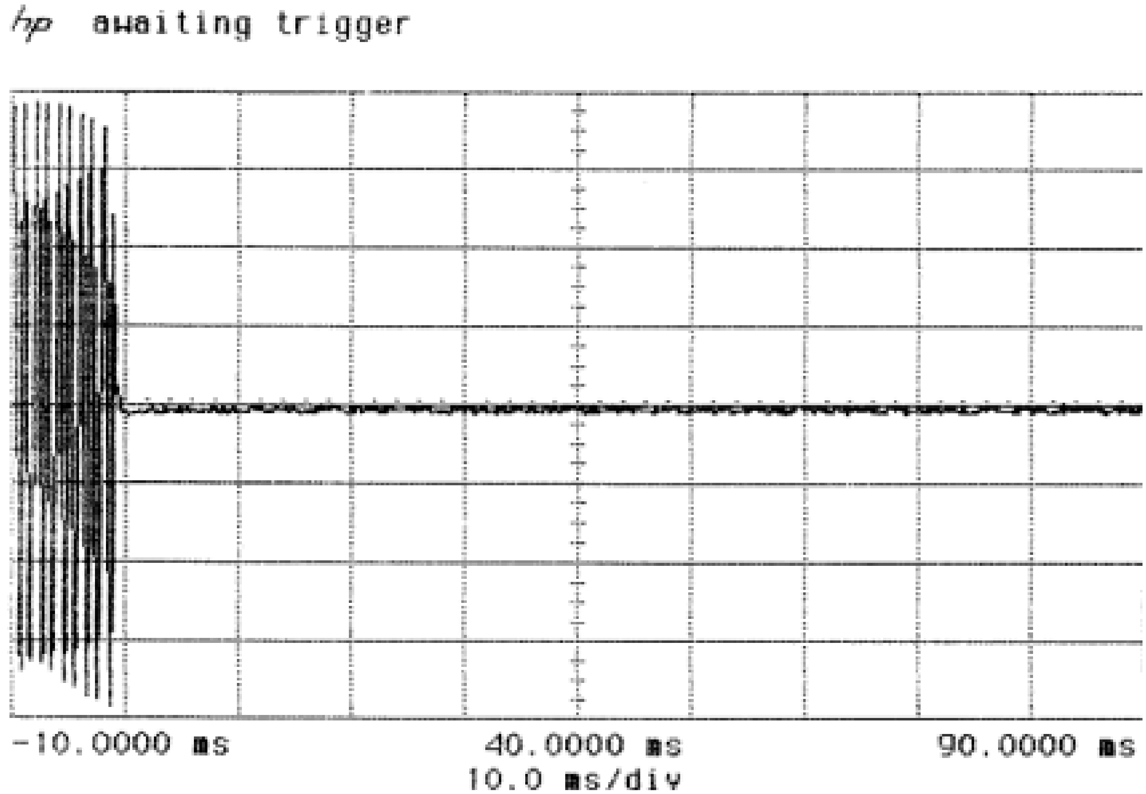
KEY UP



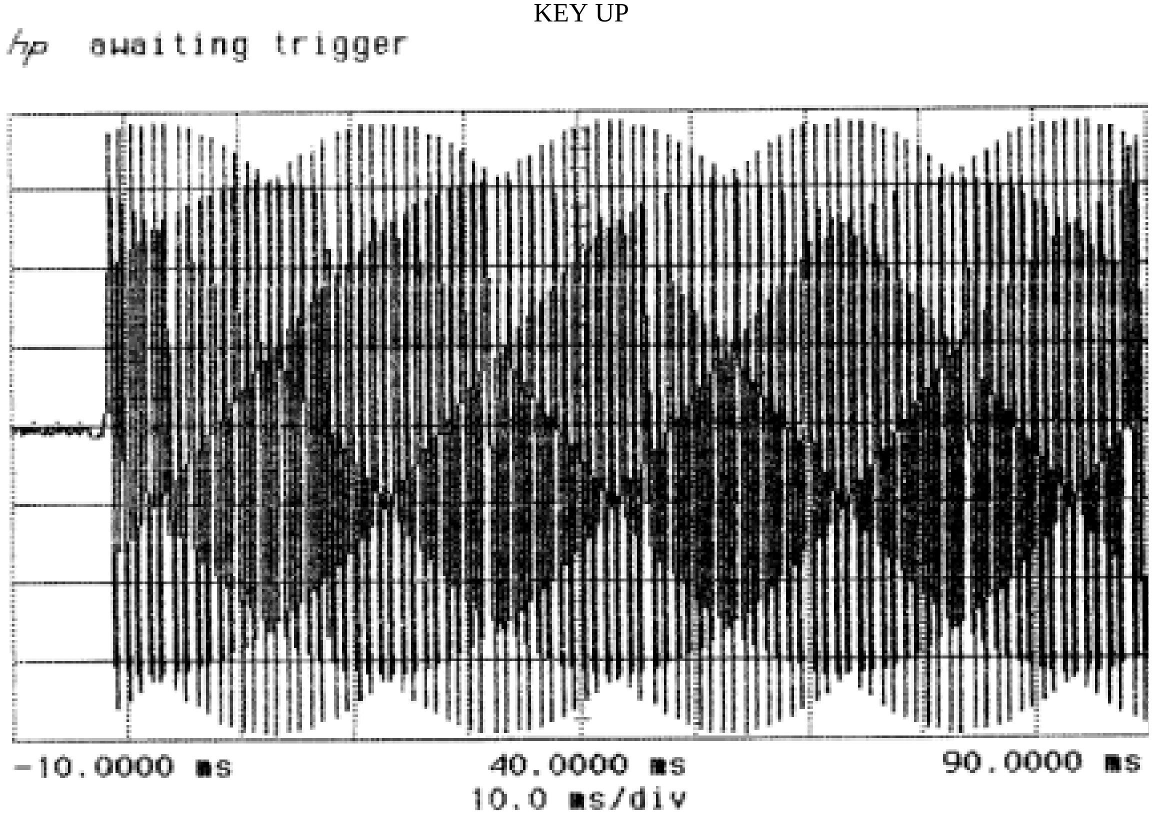
KEY DOWN

TRANSIENT FREQUENCY RESPONSE

TRANSCEIVER WITH UNMODULATED CARRIER



KEY UP



KEY DOWN