Section 5 - 2983(e) Application for type acceptance - Measurement Data and Methods

5.1 - General measurement conditions and parameters

Standard test conditions
Unless otherwise stated, the following conditions were applicable during the tests:

Ambient temperature	:	21 to 26 °C
Ambient humidity	:	40 to 60 %
DC supply	:	13.8V ± 5 %

The equipment is intended to operate from a nominal 12V DC vehicle electrical power supply The unit was aligned according to the standard alignment procedure described in Section 3.10(d)(9), Tune up procedure.

Frequency range to be investigated
The highest transmitter frequency is 162.0 MHz. Investigation was made from 1 MHz up to 10 times the carrier frequency (1620.0 MHz).

Two tone test signal Paragraph 2.985(b) of the FCC Rules, defines that the equipment should be tested when modulated simultaneously with two tones of 500 Hz and 2400 Hz. The single sideband spectrum of this equipment is, however, modified to implement the transparent tone in band technique (TTIB). This splits the audio input signal at 1.65 kHz, and shifts the upper half up by 300 Hz and the lower half down by 300 Hz. Thus, to simulate the effect of two tone modulation on a conventional SSB system, two tones can be used that produce the same RF spectrum. These tones are obtained as follows:

first tone = 500 + 300 = 800 Hz

second tone = 2400 - 300 = 2100 Hz

For convenience, this test signal can be generated internally within the equipment by a digital signal processor under the control of an external personal computer. Unless otherwise stated, the level of the test signal was increased until rated output power was achieved at the output of the transmitter.

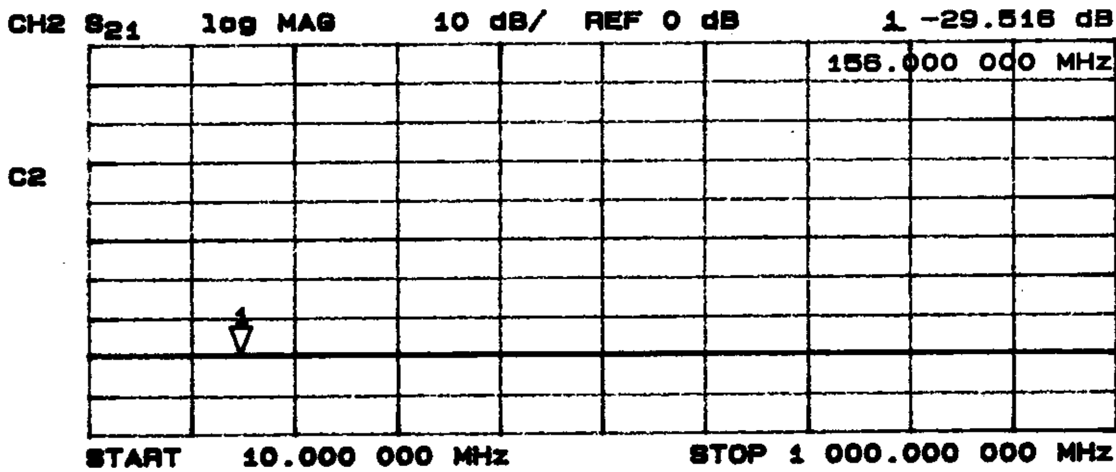
Measured Parameters

2.985	RF Output Power
2.987	Modulation Characteristics
2.989	Occupied Bandwidth
2.991	Spurious emissions at antenna terminals
2.993	Field strength of spurious radiation (in both transmit and receive mode)
2.995	Frequency stability
90.210(e)	Out of channel emissions
90.214	Transient frequency behaviour

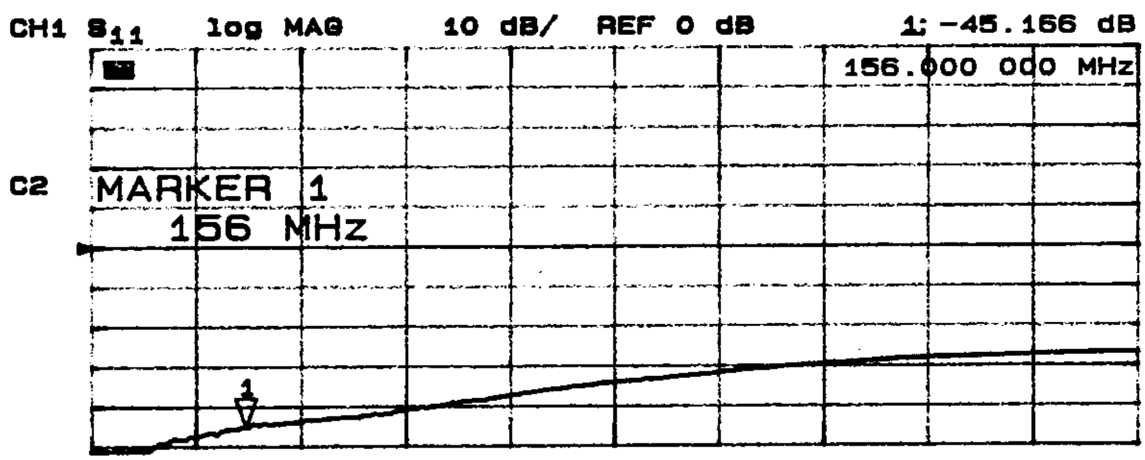
Measurements for FCC Rules Paragraphs 2.985, 2.987, 2.989, 2.991, 2.995 and 90.210(e) were carried at out the Securicor Radiocoms laboratories at Cross Keys House, Block B, Westfield Industrial Estate, Midsomer Norton, Bath, BA3 4BS, THE UNITED KINGDOM.

Measurements for FCC Rules Paragraphs 2.993, Part 15 Subpart B and 90.210(e) were carried out by an independent test house, TÜV Product Service Ltd, Snitterfield Road, Bearley, Stratford-Upon-Avon, Warwickshire, CV37 0EX, THE UNITED KINGDOM

Characteristics of RF load presented to transmitter



Insertion Loss



Return Loss

5.3 - 2.987(a) Modulation characteristics - Voice modulated response

Method

Fully modulate transmitter with 800 Hz and 2100 Hz tones to 25W PEP nominal. Measurements are made at the centre channel frequency (156.0000 MHz).

Set the spectrum analyser to 10 kHz span, RBW 100 Hz, VBW 100 Hz and positive peak detector. Measurements are made at the centre channel frequency (156.0000 MHz).

Note the level of the largest tone in the RF spectrum.

Apply a 1 kHz signal tone to the transmitter input such that the level of the resulting RF signal is the same as that produced by the tone noted above. This is taken as the 0 dB reference point.

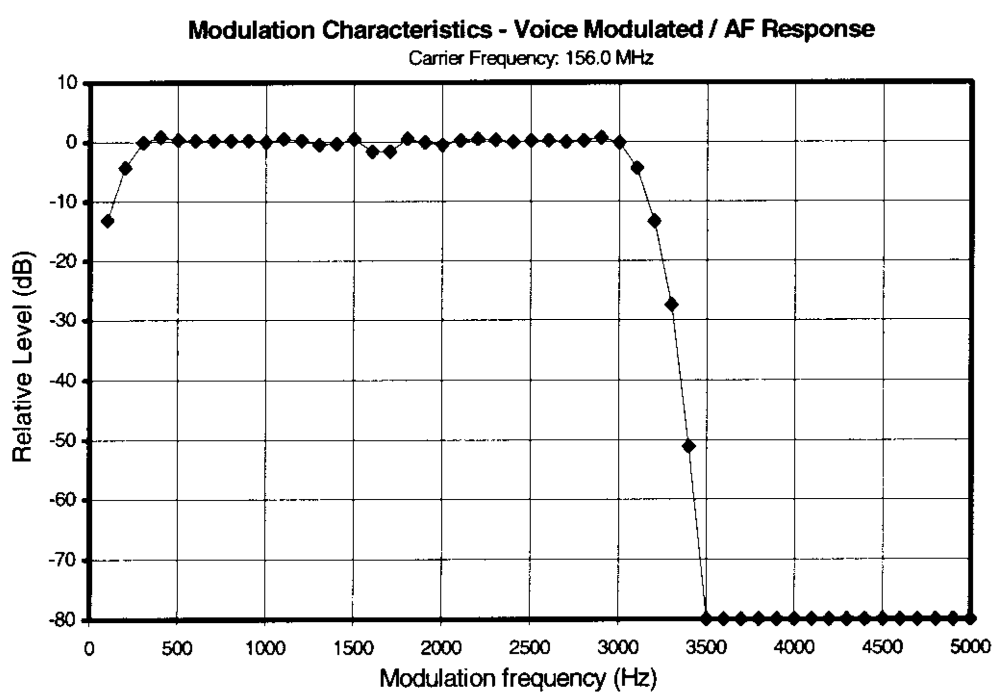
Vary the audio frequency from 100 Hz to 5000 Hz in 100 Hz steps. Note the level of the resulting tone in the RF spectrum at each point.

Results

Transmitter modulated with a single tone. Transmit frequency 156.0000 MHz.

The reference frequency for the measurement is 1 kHz.

The audio frequency of the test signal was varied from 100 Hz to 5 kHz. The audio level was maintained constant.



5.4 - 2.987(b) Modulation characteristics - Modulation limiting

Method

Fully modulate the transmitter with 800 Hz and 2100 Hz tones to 25W PEP nominal. Note the level of each tone in the resulting RF spectrum. Increase the level from zero to 10 dB above the level required to produce rated transmit power.

Measure Peak Envelope Power (PEP) in a 10 kHz Bandwidth at each level. The spectrum analyser is set to maximum hold (span 200 kHz, RBW 10 kHz, VBW 10 kHz and positive peak detector). Measurements are made at the centre frequency (156.0000 MHz).

Calculate the actual PEP using the equation:

$$P = 10^{(\frac{A+L}{10})-3}$$

Where: A is the attenuation in dB between the transmitter and the spectrum analyser
L is the maximum level measured on the spectrum analyser in dBm
P is the Peak Envelope Power (PEP)

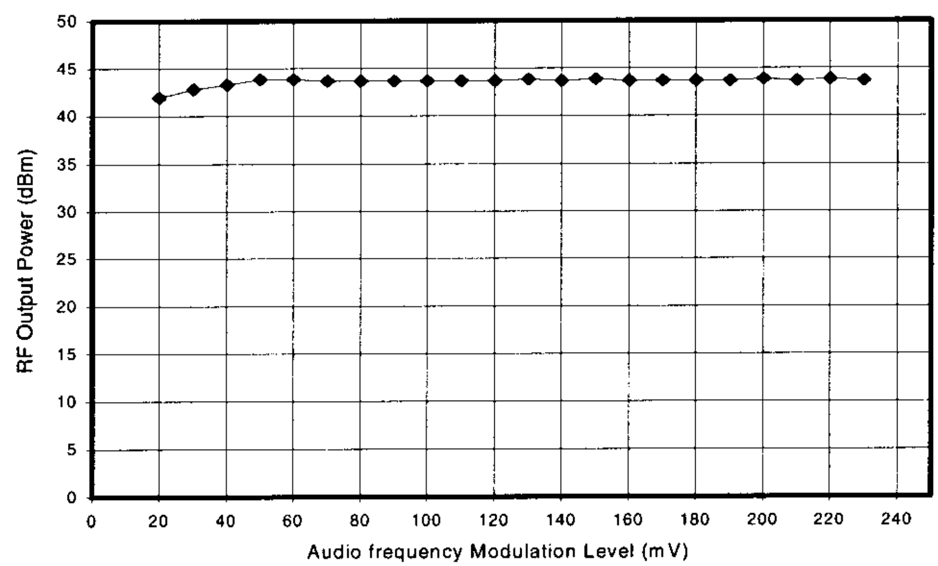
Results

Drive level is increased from zero to 10 dB above that required to produce rated output power.

Transmit frequency 156.0000 MHz

Modulation Characteristics

Limiting Carrier Frequency: 156.0 MHz



5.5 - 2.989 Occupied bandwidth

Method
Fully modulate the transmitter with 800 Hz and 2100 Hz tones to 25W PEP nominal.

Measurements are made at the centre channel frequency (156.0000 MHz).

Set the spectrum analyser to 10 kHz span, 100 Hz RBW, 100 Hz VBW, reference level 10 dB above the level of the largest signal. Use the spectrum analyser "99% occupied bandwidth" function to measure the occupied bandwidth.

Repeat test method for transmitter fully modulated with 1200 and 4400 BPS data.

Measurements are made at the centre channel frequency (156.0000 MHz).

Results
Transmitter frequency 156.0000 MHz. Transmitter fully modulated in all cases

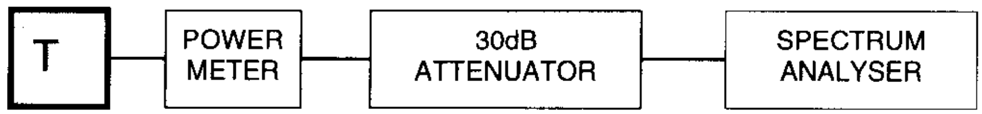
Test Signal	Occupied bandwidth (kHz)
800 Hz and 2100 Hz tones	2.08
1200 BPS data	1.98
14400 BPS data	3.15

5.6 - 2.991 / 90.210(e) Spurious emission at antenna terminals

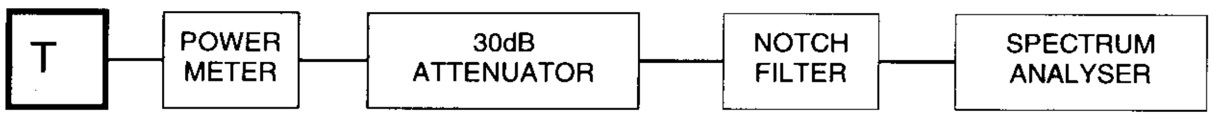
Method

For all measurements of signals at the antenna port, the equipment was configured as shown below:

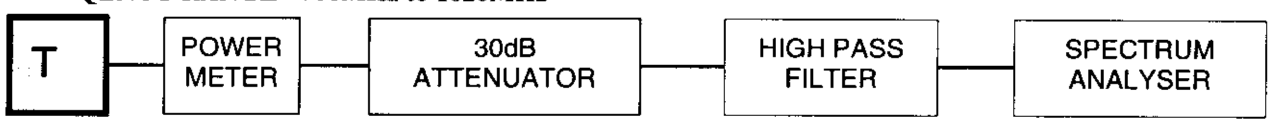
FREQENCY RANGE - 1MHz to 400MHz



FREQENCY RANGE - 400MHz to 700MHz



FREQENCY RANGE - 700MHz to 1620MHz



1. Measure the attenuation vs. frequency of the first set-up over the frequency range 1 MHz to 1620 MHz.
2. Set the transmitter to 156.0000 MHz. Fully modulate the transmitter with the standard 2 tone test signal.
3. Fully modulate the transmitter with 800 Hz and 2100 Hz tones to 25W PEP nominal. Measure Peak Envelope Power (PEP) in a 10 kHz bandwidth. The spectrum analyser is set to maximum hold, with a span 200 kHz, RBW 10 kHz, VBW 10 kHz and positive peak detection.
4. Calculate the actual PEP using the equation:

$$P = 10^{(\frac{A+L}{10})-3}$$

Where: A is the attenuation I dB measured in step 1.
L is the maximum level measured on the spectrum analyser in dBm in step 3.
P is the Peak Envelope Power.

5. Calculate the maximum required attenuation using the equation:

$$ATTEN=55+10log(P)$$

6. A search is now made for all products within 20 dB of the calculated limit:

Set the spectrum analyser to 25 MHz span, 10 kHz RBW, 10 kHz VBW positive peal detect and reference level equal to L measured above.

Over a frequency range from 1 MHz to 1620 MHz, observe the spectrum in 20 MHz steps, identify all spurious signals and note the frequency.

7. At all frequencies where products **250 kHz or more from the carrier** are identified, detailed measurements are now made.

To avoid errors due to harmonics generation in the spectrum analyser, measurements at frequencies at or above the second harmonic frequency should be made with either a notch or high pass filter in place. This is shown in the set-up diagram.

Set the spectrum analyser to 200 kHz span, 10 kHz VBW, positive peak detect and reference level equal to L measured above.

Locate each previously identified spurious signal, set the analyser to maximum hold and measure the maximum level of each signal. Note the frequency and the level. Repeat for all spurious signals.

At all frequencies where spurious products were measured, measure the attenuation of the path from the transmitter output to the spectrum analyser input.

8. A search is now made for all spurious signals **250 kHz or less from the carrier**:

Set the spectrum analyser to 20 kHz span, 100 Hz RBW, 100 Hz VBW, positive peak detect, centre frequency equal to the carrier frequency.

Measure the level of the largest signal. Calculate the power of the largest signal using the equation:

$$P = 10^{(\frac{A+L}{10})-3}$$

Where: A is the attenuation in dB measured in step 1
L is the maximum level measured on the spectrum analyser in dBm in step 8
P is the Peak Envelope Power

Calculate the minimum required attenuation using the equation:

$$ATTEN=55+10log(P)$$

Set the spectrum analyser to 600 kHz span, 100 Hz RBW, 100 Hz VBW, positive peak detector, reference level equal to 10 dB above L measure above.

Locate each previously identified spurious signal, set the analyser to maximum hold and measure the maximum level of the signal. Note the frequency and the level. repeat for all spurious signals.

Results

For signals more than 250 kHz from the carrier, measurements are made with 10 kHz RBW and VBW for signals less than 250 kHz from the carrier, measurements are made with 100 Hz RBW and VBW.
Transmitter fully modulated with 800 Hz and 2100 Hz tones at 156.0000 MHz.

a) Signals more than 250 kHz from carrier

True level calculated using the equation.

$$P = 10^{(\frac{A+L}{10})-3}$$

Measured level of the transmit signal in 10 kHz bandwidth (L)	=	14.46 dBm
Attenuation at 156.0000 MHz (A)	=	29.51 dB
Power of transmit signal (P)	=	24.95 W (43.97 dBm)

Minimum required attenuation of spurious emissions is calculated using the equation:

$$ATTEN=55+10log(P)$$

Minimum required attenuation is therefore = 68.97 dB

Maximum allowed level of spurious signal is 43.97 - 68.97 dBm = -25.0 dBm

True level (dBm) = Measured level (dBm) + Attenuation (dB) = L + A

Level below the limit (dB) = -25.0 dBm - True level (dB)

Maximum allowed level of Spurious signals is -25.0 dBm

b) Signals less than 250 kHz from the carrier
True level calculated using the equation.

$$P = 10^{(\frac{A+L}{10})-3}$$

Measured level of the transmit signal in 100 Hz bandwidth (L)	=	5.77 dBm
Attenuation at 156.0000 MHz (A)	=	29.51 dB
Power of transmit signal (P)	=	3.37W (35.28 dBm)

Minimum required attenuation of spurious emissions is calculated using the equation:

$$ATTEN=55+10log(P)$$

Minimum required attenuation is therefore = 60.28 dB

Maximum allowed level of spurious signal is 35.28 - 60.28 dBm = -25.0 dBm

True level (dBm) = Measured level (dBm) + Attenuation (dB) = L + A

Level below the limit (dB) = -25.0 dBm - True level (dB)

Maximum allowed level of Spurious signals is -25.0 dBm

Results

Transmitter fully modulated with 800 Hz and 2100 Hz tones.

Maximum allowable level of spurious signal is -25.0 dBm

All signals within 20 dB of the limit are reported (-45.0 dBm)

Frequency	Measured Level (L)	Attenuation (A)	True Level	Margin
MHz	dBm	dB	dBm	dB
131.9985	-66.41	29.51	-36.9	-11.9
131.9992	-64.91	29.51	-35.4	-10.4
132.0000	-73.74	29.51	-44.23	-19.23
132.0004	-61.08	29.51	-31.57	-6.57
132.0011	-65.24	29.51	-35.73	-10.73
132.0023	-66.88	29.51	-37.37	-12.37
179.9981	-66.58	29.51	-37.07	-12.07
179.9988	-72.58	29.51	-43.07	-18.07
179.9992	-72.08	29.51	-42.57	-17.57
180.0000	-62.68	29.51	-33.17	-8.17
180.0007	-72.08	29.51	-42.57	-17.57
180.0019	-67.68	29.51	-38.07	-13.07
312.0004	-70.74	29.51	-41.23	-16.23
468.0017	-74.08	29.51	-44.57	-19.57

Frequency	Measured Level (L)	Attenuation (A)	True Level	Margin
MHz	dBm	dB	dBm	dB
155.9962	-62.67	29.51	-33.16	-8.16
155.9947	-66.57	29.51	-37.06	-12.06
155.9636	-71.73	29.51	-42.22	-17.22
155.9358	-71.9	29.51	-42.39	-17.39
156.0011	-70.23	29.51	-40.72	-15.72
156.0041	-65.57	29.51	-36.06	-11.06
156.0048	-62.51.	29.51	-33	-8

List of test equipment used for measurement and testing

Equipment	Model Number	Manufacture	Serial Number	Comments
Spectrum Analyser	HP8560E	Hewlett Packard	3240A00299	
Power Meter	2618	Bird Electronic Corp.	None	100-250 MHz, 50W
Audio Signal Generator	HP8904A	Hewlett Packard	2948AC5933	DC-600 kHz
Power Supply	9202287	Isotech	LMT 137	16V, 10A
Attenuator	8306-300-30dB	Bird	ATT 009	30dB, 250W
Notch Filter	NR-160-1CN	Aerial Facilities Ltd	None	162.5 MHz, 50W
RF Signal Generator	HP8657A	Hewlett Packard	3430U02733	
Network Analyser	HP8753B	Hewlett Packard	2716U00828	
Digital Volt meter	77	Fluke	UCL0087746	

90.210(e) Spurious emissions within 10 kHz of carrier / transmit mask

Method
The measurement method is in accordance with TIA/EIA TSB57.

All measurements are made with 20 kHz span, 100 Hz RBW and 100 Hz VBW, reference level is 10 dB above the level of the highest emission.

1. The transmitter is fully modulated with 800 Hz and 2100 Hz tones at the centre channel frequency.

2. The signal is applied to a spectrum analyser through a suitable attenuator.

   The spectrum analyser is set to the centre channel frequency, 20 kHz span, 100 Hz RBW, 100 Hz VBW, positive peak detector and max hold.

   The reference level is set so that the highest level of the emission is 10 dB below the spectrum analyser reference level.

3. The power level of the highest emission in the authorised bandwidth (P), is calculated using the formula:

$$P = 10^{(\frac{A+L}{10})-3}$$

   Where: A is the attenuation between the transmitter and the spectrum analyser.
   L is the level of the highest emission in the 6 kHz bandwidth as viewed on the spectrum analyser in dBm

4. The spectrum analyser display is plotted and the mask is superimposed on the plot.

   The mask limits are as follows:

   4.1 The attenuation required between 3 and 4.6 kHz is the lesser of :

   a) $30 + 16.66 (f_d - 3)$ dB
   b) $55 + 10 \log (P)$ dB
   c) 65 dB

   Where f_d is the displacement from the carrier frequency.

   4.2 The minimum ultimate attenuation required for displacement frequencies equal to or greater than 4.6 kHz is calculated using the formula:

$$ATTEN=55+10\log(P)$$

5. The measurement process is repeated for a transmitter fully modulated with 1200 BPS data.
6. The measurement process is repeated for a transmitter fully modulated with 14400 BPS data.

Results
Transmitter frequency 156.0000 MHz. The transmitter was fully modulated in all cases.

Test Signal	Level of Highest Emission (L)	Attenuation (A)	Power of Highest Emission (P)	Required Attenuation $f_d = 3$ kHz	Required Attenuation $f_d = 4$ kHz	Required Attenuation $f_d = 4.6$ kHz	Ultimate Attenuation $f_d > 4.6$ kHz
	dBm	dB	W	dB	dB	dB	dB
800 Hz and 2100 Hz	5.77	29.51	3.37	30	46.67	56.67	60.27
1200 BPS FFSK	5.67	29.51	3.29	30	46.67	56.67	60.18
14400 BPS Data	3.13	29.51	1.84	30	46.67	56.67	57.64

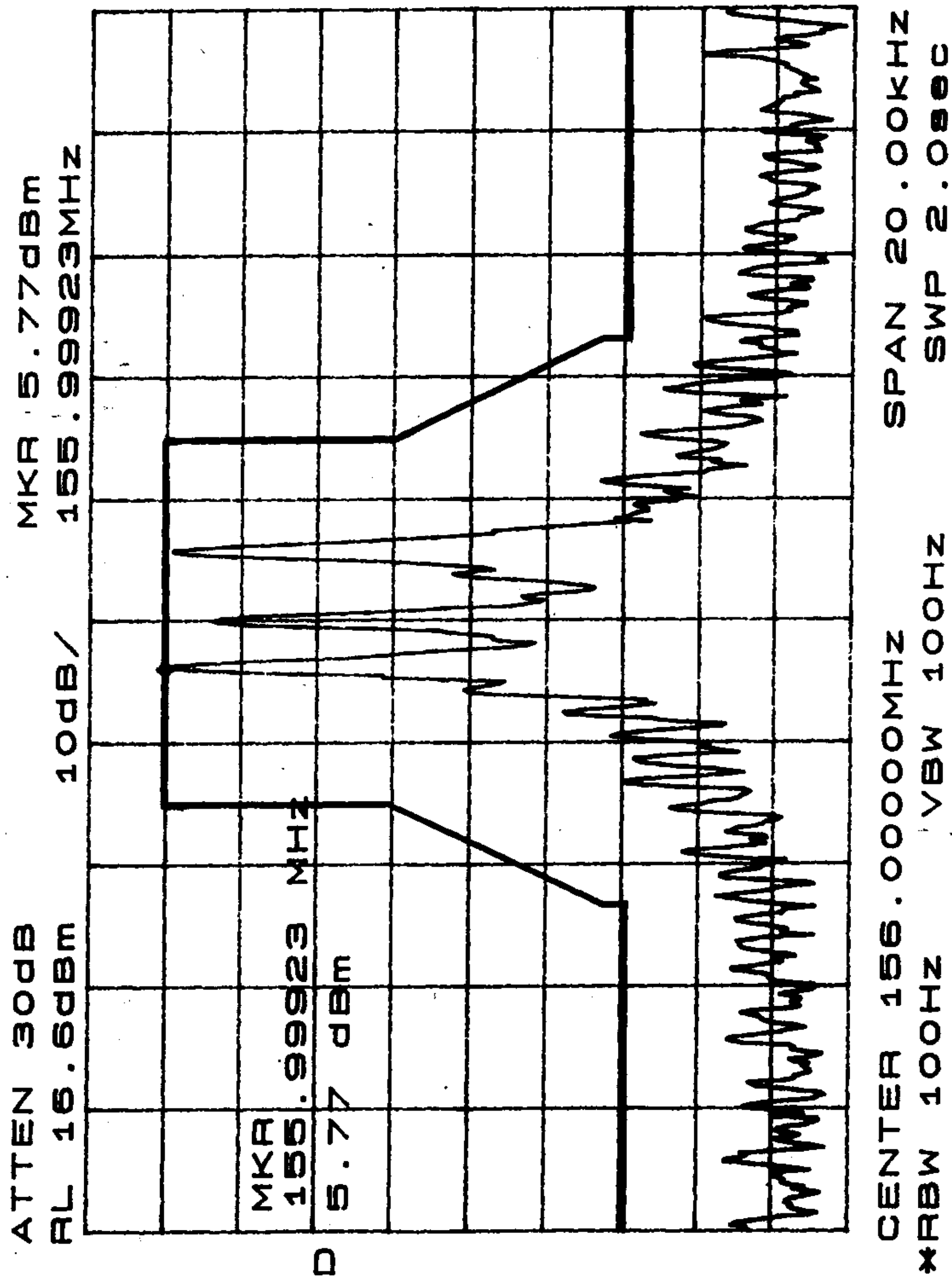
Refer to the attached 2 plots with superimposed transmitter masks:

Plot 1 - 800 Hz and 2100 kHz tones

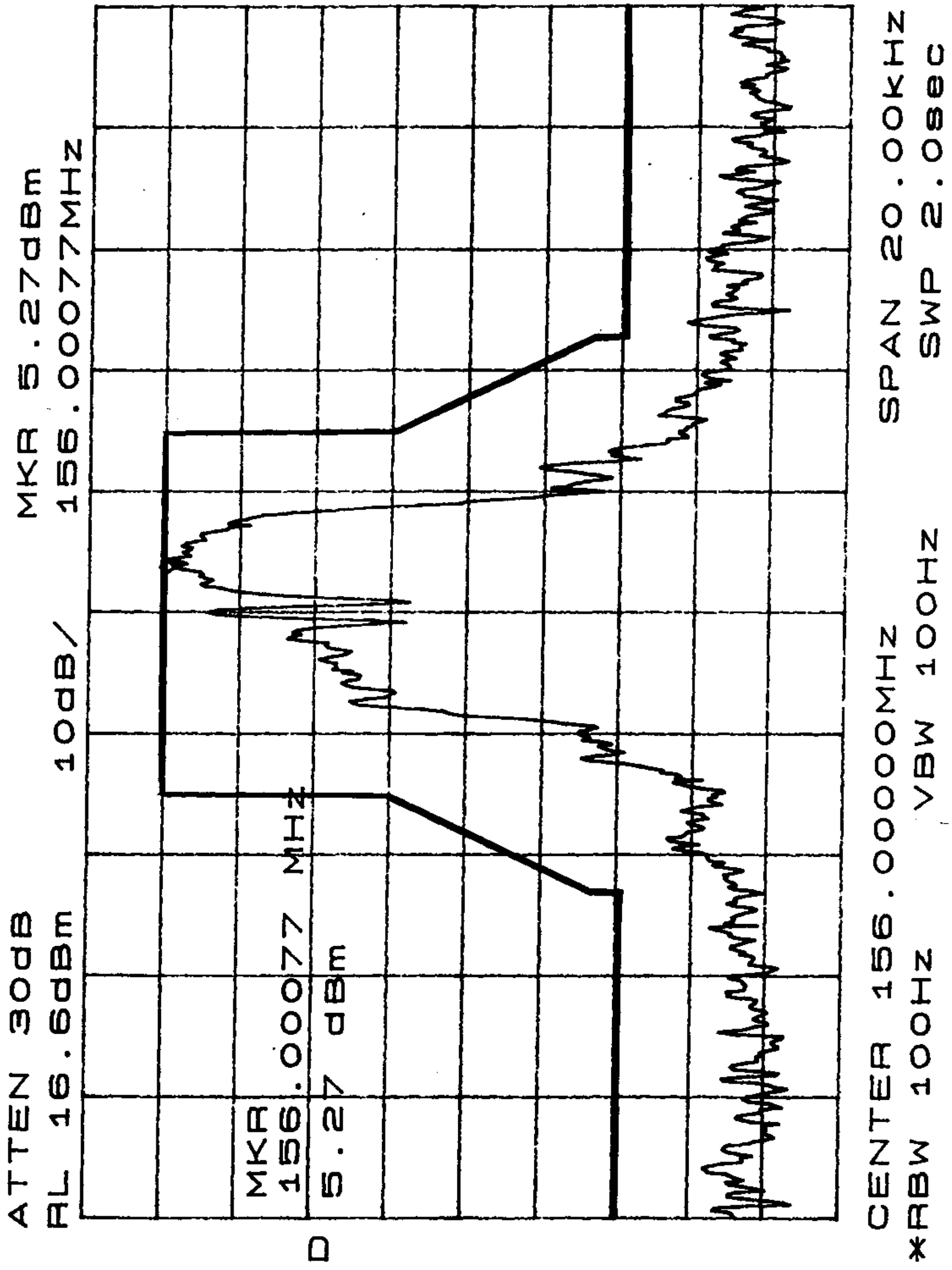
Plot 2 - 1200 BPS (FFSK) data

Plot 3 - 14400 BPS (128 QAM) data

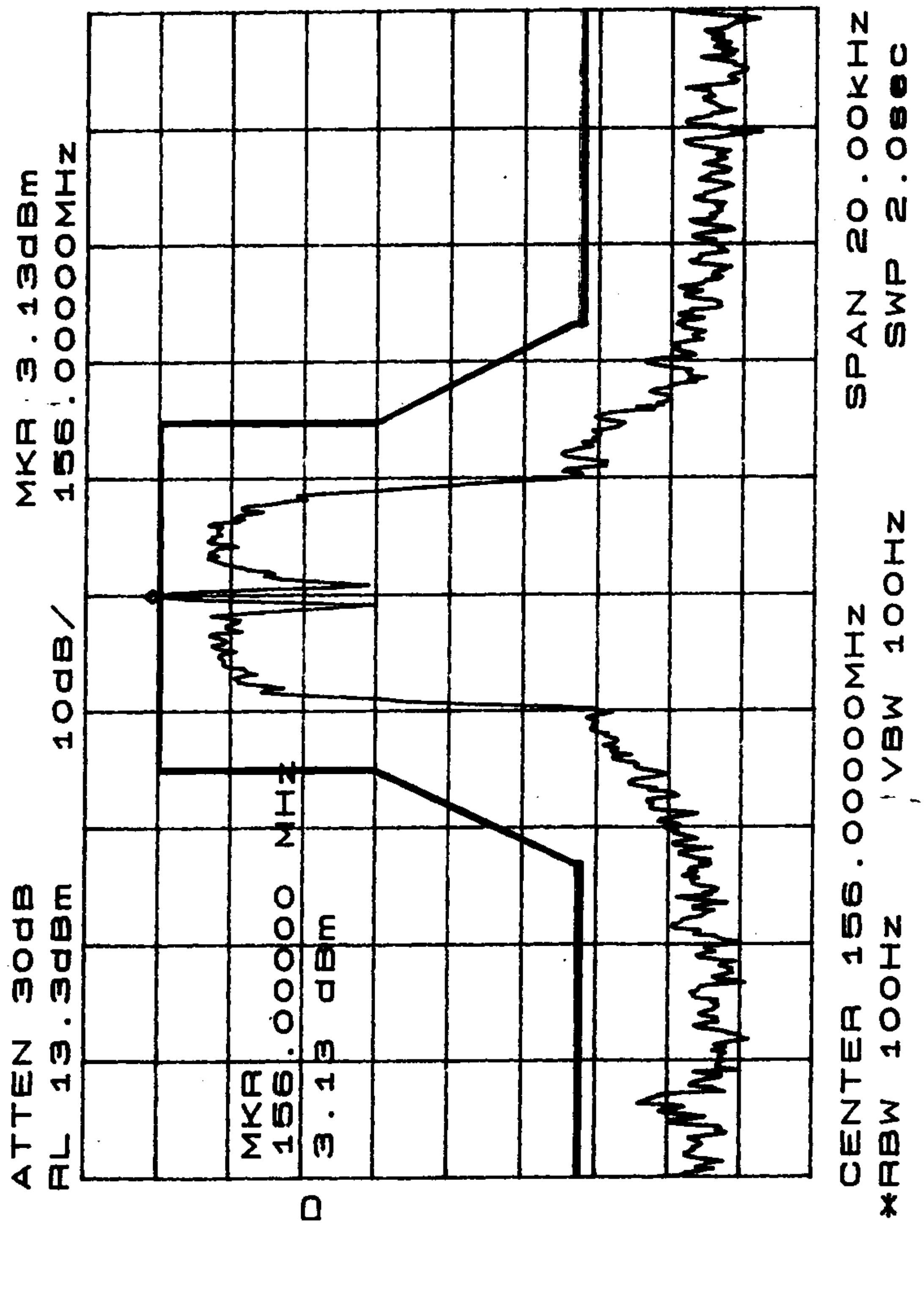
Plot 1 - 800 Hz and 2100 kHz tones



Plot 2 - 1200 BPS (FFSK) data


ATTEN 30dB
RL 16.6dBm
10dB/
MKR 5.27dBm
156.00077MHz
D
MKR
156.00077 MHz
5.27 dBm
CENTER 156.00000MHz
*RBW 100Hz
VBW 100Hz
SPAN 20.00kHz
SWP 2.0sec

Plot 3 - 14400 BPS (128 QAM) data



5.7 - 2.993 Field strength of radiated spurious emissions

Method
In transmit mode the unit meets the requirements of FCC Rules Part 90, Paragraph 90.210(e) for radiated spurious emissions. The results for this test are recorded below. The minimum required attenuation relative to the wanted transmit signal is given by:

$$ATTEN = 55 + 10\log(P)$$

(Where P is the measured power, in Watts, of the highest emission signal in the authorised bandwidth).

For 25 Watt transmit power, the attenuation must be 69.0 dB or more below P.

Results

The frequency spectrum from 30 MHz to 2.3 GHz was investigated. However no radiated spurious emissions were discovered within 20 dB of the permissible limit calculated in the equation above. Therefore no measurements were recorded.

5.8 - Compliance statement for radiated emissions to FCC Rules Part 15

In RECEIVE mode, the LMM4113D meets the requirements of FCC rule Part 15 Subpart B (unintentional radiator) for Radiated Electric Field Strength Emissions.

Testing was conducted at TÜV Product Service Ltd, Snitterfield Road, Bearley, Basingstoke, Stratford-Upon-Avon, Warwickshire, CV37 0EX, THE UNITED KINGDOM. A test report (Report No. BO604140/1) demonstrating compliance is held on file at Linear Modulation Technology Inc. and is available for review on request.

5.9 - 2.995/90.213 Frequency stability (with temperature, supply voltage and time)

2.995(a)(1) - Frequency stability with temperature
As explained in 3.11, the Mobile reference oscillator frequency is locked to the Base Station. The mobile will not transmit unless it is locked to the Base Station. The AFC circuitry in the mobile has a range of greater than ±5 ppm, compared with a specified drift for the mobile frequency reference over the -30°C to +70°C temperature range of ±2.5 ppm. Therefore the Mobile will always be able to lock to the base station.

Therefore the fundamental frequency drift with temperature of the mobile will always be the same as that of the Base Station. The performance of the Base Station Frequency Standard FQS-A is detailed in the submission for the LMC3003 Base Station.

2.995(d)(1) - Frequency stability with supply voltage

Method
The only cause of drift in the mobile transmit frequency are short term temperature variation within the mobile housing during a transmit period and variation due to supply voltage. A graph showing variation of frequency during transmit can be found in section 5.9 - 2.995 Frequency Stability (this section). The supply to the Mobile reference oscillator is filtered and double regulated to minimise the effect of changes in

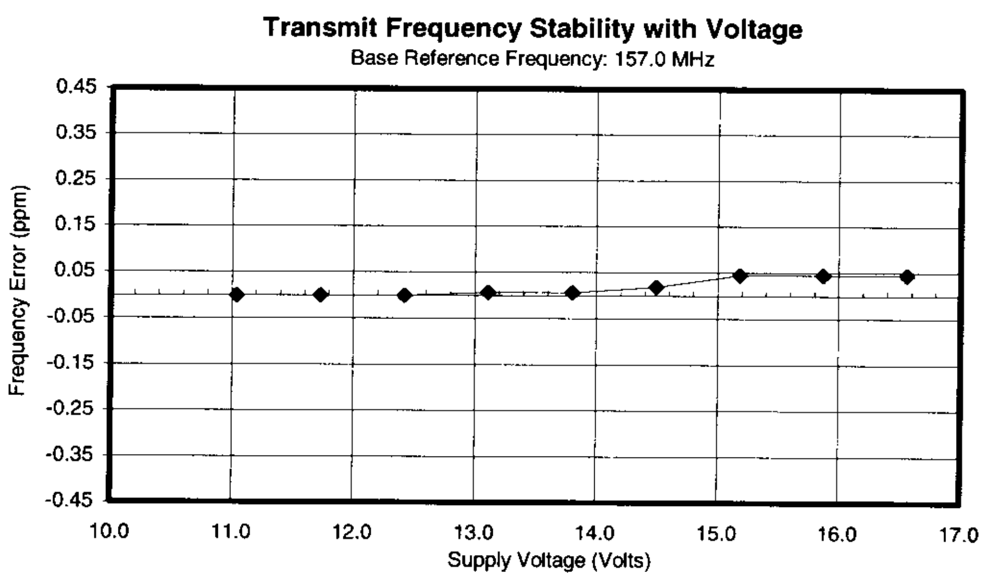
supply voltage. The variation with change in supply voltage has been measured and the results are given below.

Mobile frequency stability with supply voltage

80% of supply voltage	:	11.04 V
Nominal supply voltage	:	13.80 V
120% of supply voltage	:	16.56 V

The mobile supply voltage was set to 13.80 V and the Mobile receiver locked to a Base Station. It was then switched to transmit and the frequency was measured. The supply voltage was then increased from the minimum to the maximum in steps of 5%. At each step the transmit frequency was measured and recorded.

Results
Over the specified supply voltage range, the transmit frequency changed by less than ± 7 Hz. This is a change of less than 0.05 ppm. This change is insignificant compared to the measured 0.19 ppm change due to temperature during a 4 minute transmit period. It is likely that any measured changes due to supply voltage variation will be masked by temperature drift during the time taken to make the measurements. Results are included below.

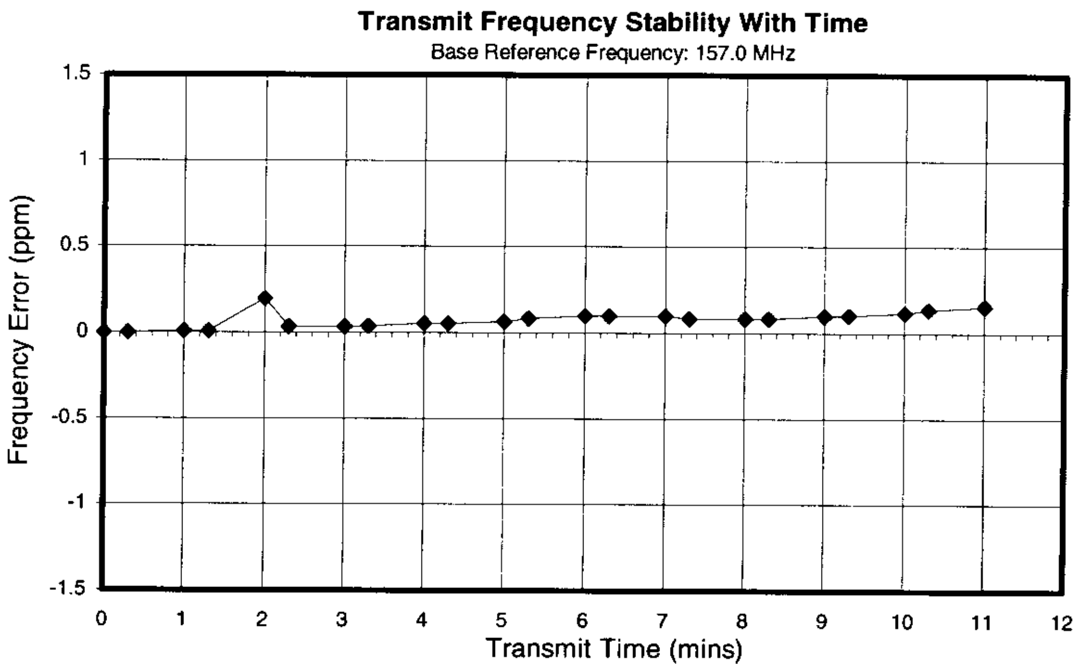


2.995(e) - Frequency Stability with time

Method
As explained in Section 3.11 , the frequency stability of the mobile transceiver is primarily defined by the base station reference to which it is synchronised. This will be better than ±0.1 ppm.

In addition, the mobile transceiver may drift in frequency with time when operating in transmit mode. Note that the maximum transmit time is 4 minutes. This time is controlled by the Signal Processing Unit (SPU). To measure
transmit frequency drift, a mobile was first locked to and accurate frequency reference (in receive mode) at a frequency of 156.0000 MHz. The mobile was then set to transmit a two tone test signal at maximum PEP. The frequency of the transmitted pilot tone was measured at 30 second intervals for 10 minutes. The test was carried out at room temperature. The frequency stability specified in the FCC Rules (Part **90.213**) for a mobile unit is ±2.0ppm.

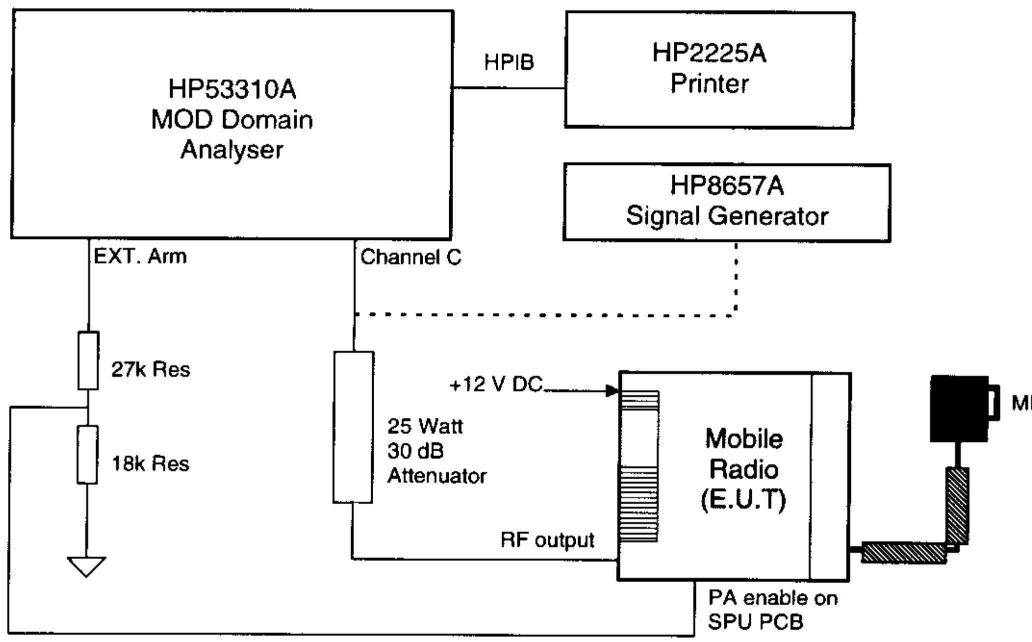
Results



5.10 - 90.214 Transient frequency behaviour

In order to measure the frequency stability of the radio with time when the transmitted RF power is switched on a Modulation Domain Analyser was used.

The diagram below illustrates the test configuration used.



Test Method

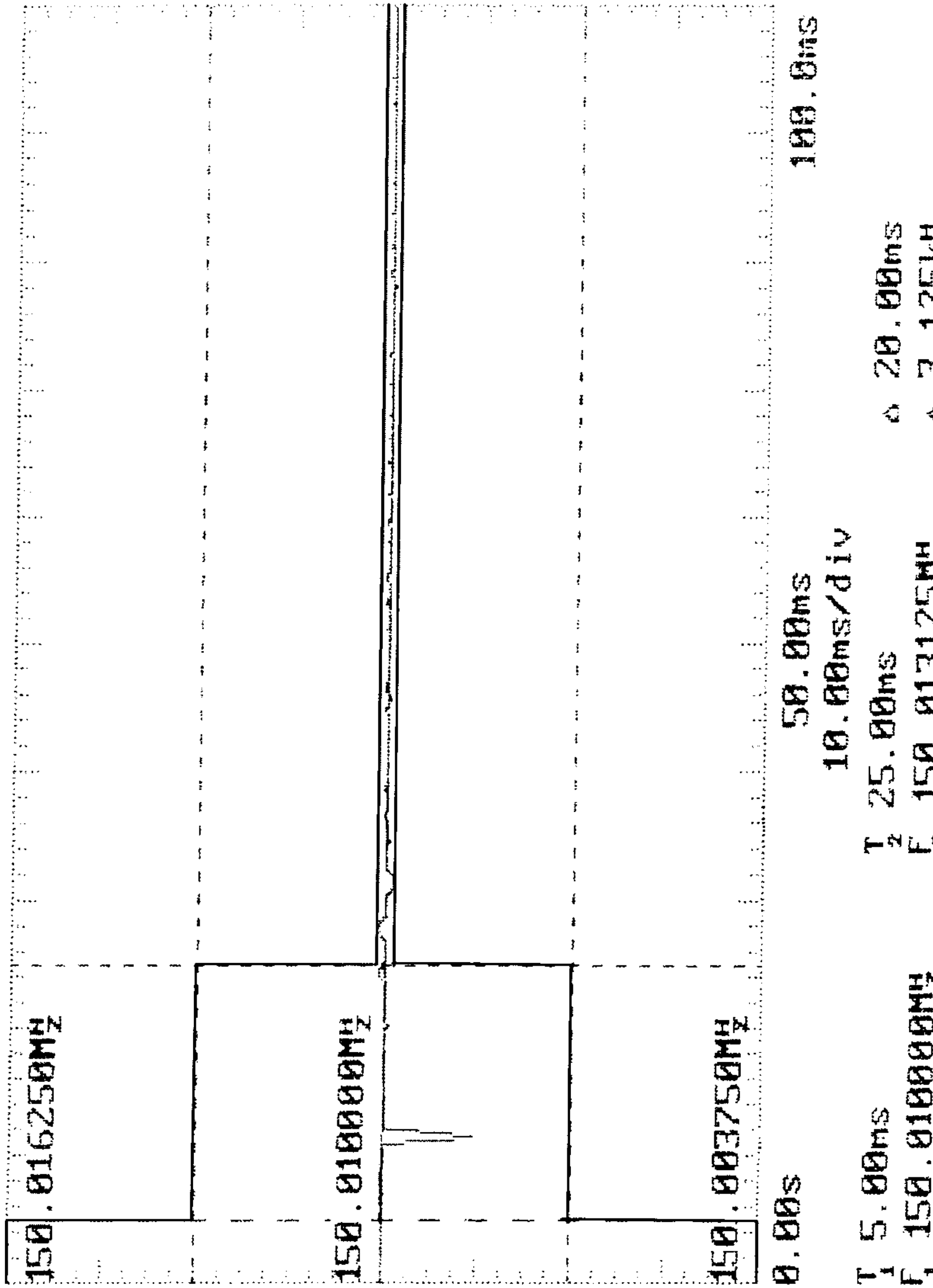
1. Set the transmitter to 150.0100 MHz. (lowest channel). The mobile is then "locked on " to a reference frequency from the signal generator.
2. Connect the RF output from the mobile to the MOD Domain Analyser via a 30 dB attenuator.
3. Configured the transmitter to transmit a pilot tone when keyed up.
4. The PA enable signal from the SPU is used to trigger the analyser to capture the wave form.
5. Set the Analyser to 150.0100 MHz with a span of 100.0 ms.
6. The transmitter is keyed up by pressing the PTT.

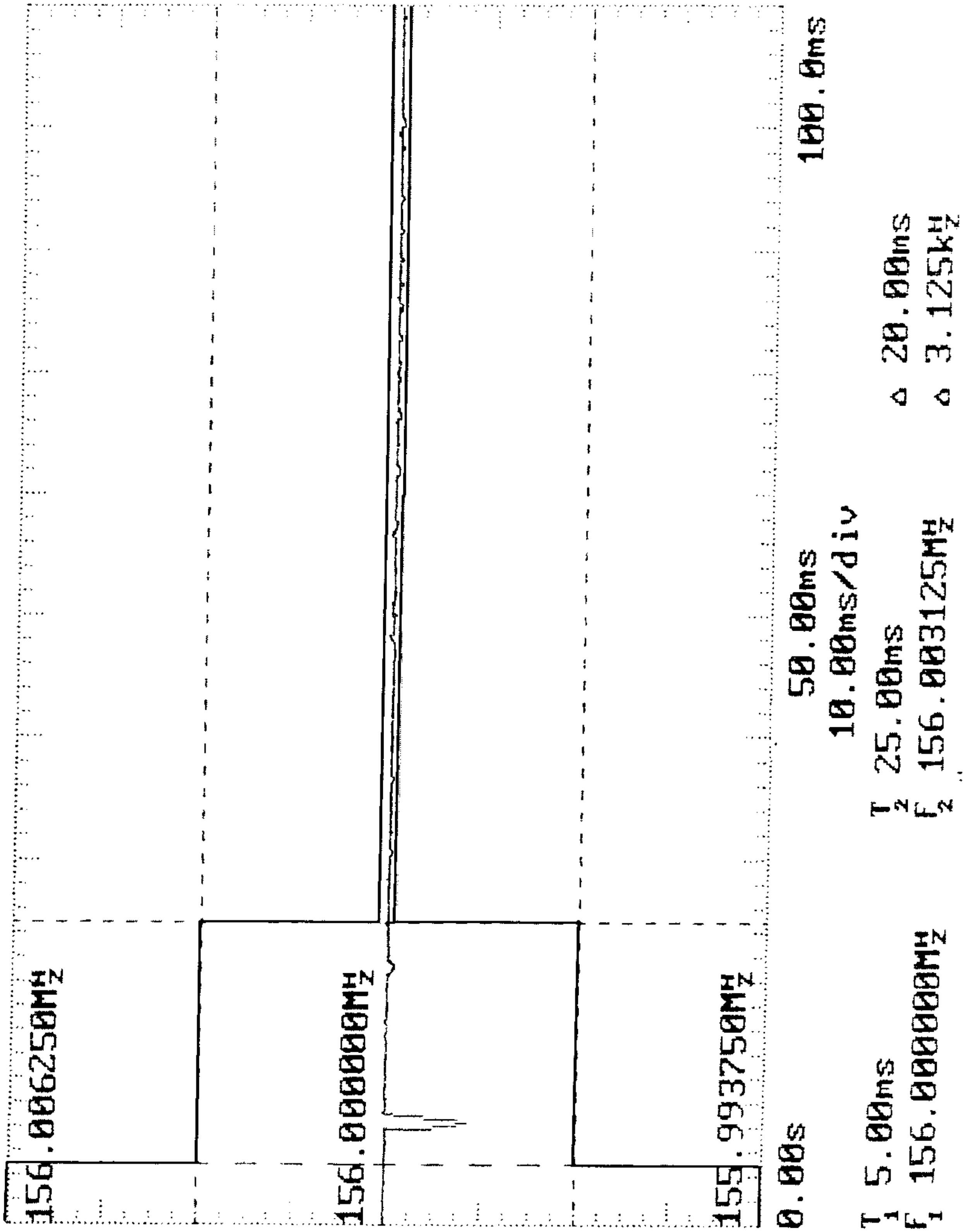
Measurements are made on the lowest, centre and highest channel frequencies.

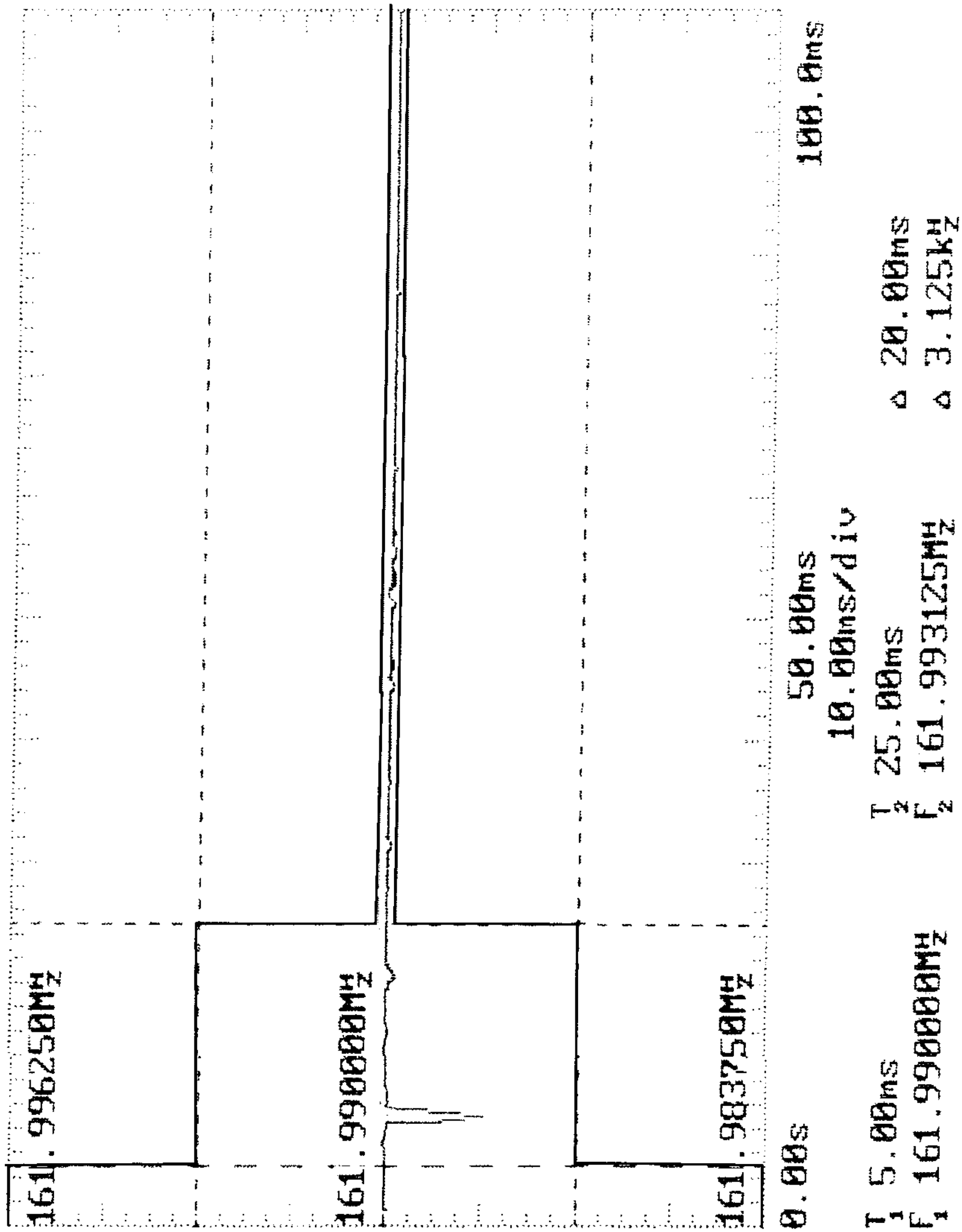
Results

The results of the measurement shown on the following pages demonstrate that the transmitter complies with the requirements of §90.214

The maximum frequency difference limits and there corresponding time intervals are shown on the plots


150.016250MHz
150.010000MHz
150.003750MHz
0.00s
50.00ms
10.00ms/div
100.0ms
T_1 5.00ms
F_1 150.010000MHz
T_2 25.00ms
F_2 150.013125MHz
Δ 20.00ms
Δ 3.125kHz


156.006250MHz
156.000000MHz
155.993750MHz
0.00s
50.00ms
10.00ms/div
100.0ms
T1 5.00ms
F1 156.000000MHz
T2 25.00ms
F2 156.003125MHz
Δ 20.00ms
Δ 3.125kHz


161.996250MHz
161.990000MHz
161.983750MHz
0.00s
50.00ms
10.00ms/div
100.0ms
T1 5.00ms
F1 161.990000MHz
T2 25.00ms
F2 161.993125MHz
Δ 20.00ms
Δ 3.125kHz