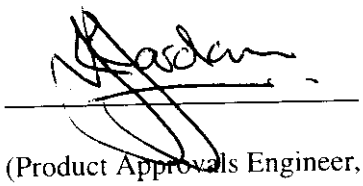
GENERAL INFORMATION AND TEST DATA IN ACCORDANCE WITH FCC RULES AND REGULATIONS , CFR47 PART 2.

FCC ID : K7DLMM4113D

MODEL : LMM4113D 25 Watt LM Mobile Transceiver

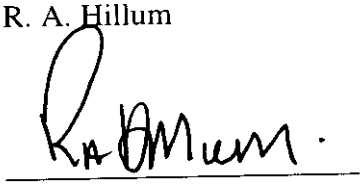
APPLICANT : Linear Modulation Technology Inc.

PREPARED BY : N. J. Jordan



(Product Approvals Engineer, Linear Modulation Technology Inc.)

APPROVED BY : R. A. Hillum



(Director of Technology, Linear Modulation Technology Inc..)

DATED : March 20, 1998

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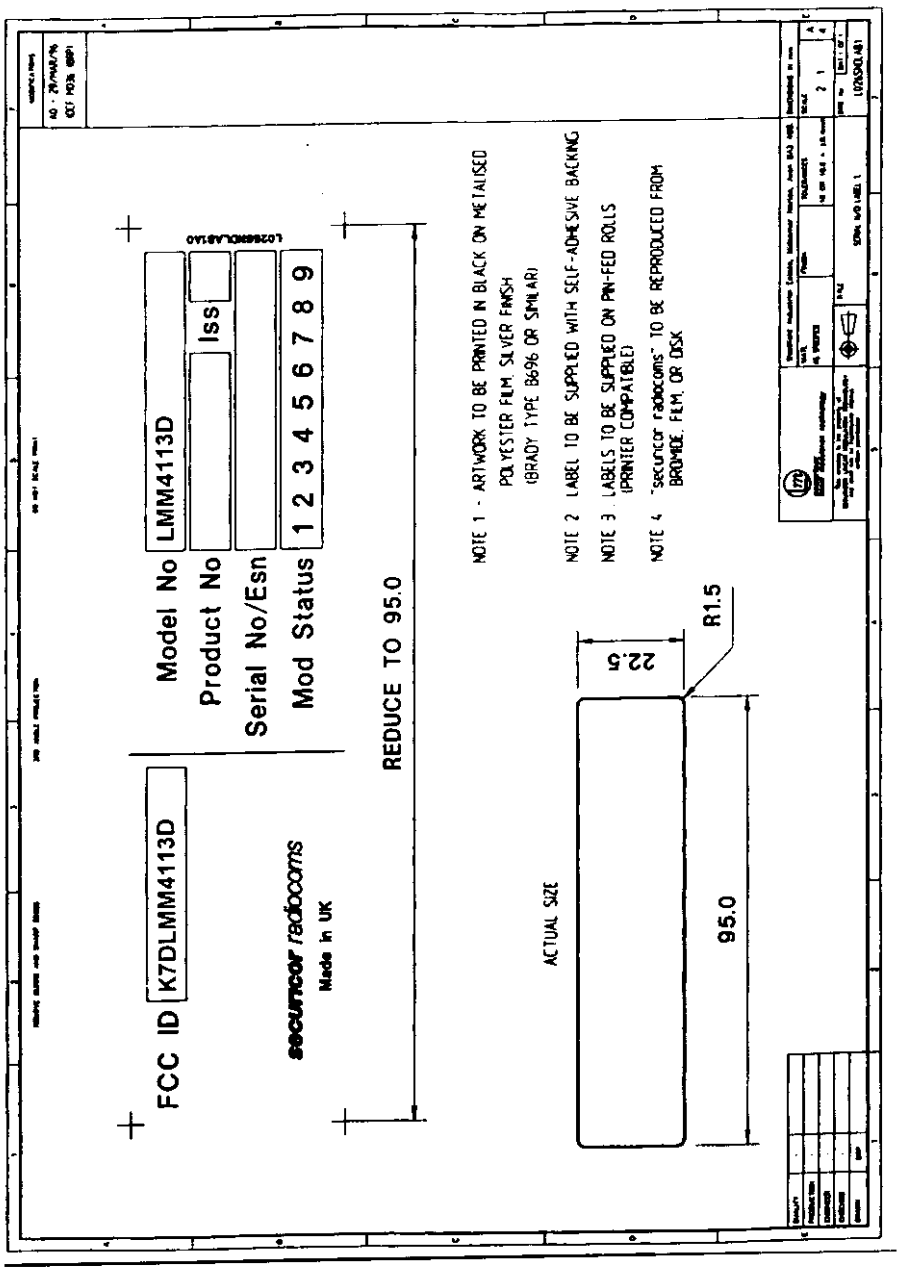
1.3 - Identifier Label Drawing



Section 2 - 2.983 Application for type acceptance - Applicant Information

2.1 - (a) Applicant

The full name and address of the applicant is stated below:

Linear Modulation Technology Inc.
Intek Global House
Westfield Industrial Estate
Midsomer Norton
Bath
Avon
BA3 4BS
The United Kingdom

Note: Linear Modulation Technology (LMT) is a trade mark of **Intek Global Corp.**

2.2 - (c) Production quantity

Production of more than one unit is planned.

Section 3 - 2.983 Application for type acceptance - Technical Information

3.1 - Overview of equipment tested

The LMM4113D is a mobile radio designed for operation on 7.5 kHz channel assignments. A modulation scheme called Linear Modulation (LM) is used, which is spectrally efficient and provides a medium particularly suited to the varying propagation effects (e.g. multi-path and Doppler) encountered in a typical mobile environment.

The mobile radio operates in two frequency simplex mode in the 150 - 162 MHz band (150 - 162 MHz mobile transmit, 150 - 162 MHz mobile receive).

In addition to voice traffic, the LMM4113D is also designed to operate with data signals which are used for digital trunking control (typical digital trunking control signals would be 1200 BPS FFSK) and High Speed Data (rates of up to 14400 BPS can be achieved). To ensure that all data transmissions remain within the specified Authorised Bandwidth, the transmit signals are passed through very steep baseband filters. This filtering is implemented using Digital Signal Processing (DSP).

The LMM4113D is self contained in a compact DIN size unit and is designed to be mounted in the drivers compartment of a road vehicle.

3.2 - Description of the LMM4000 mobile radio series variants

The LMM4000 series is a family of mobile radio products which utilise the LM modulation scheme. The series is based on a hardware platform which is common across the series. Variants of this common hardware have been developed to fulfil particular customer and market requirements. This has been accomplished by tailoring the specification and features available on each product.

The common hardware platform consists of the following:

- **Signal Processing Unit (SPU)**
- **Radio Frequency Unit (RFU)**
- **Power Amplifier (PA)**

The function of these main circuits is explained in section 3.3.

This core hardware can be combined with additional hardware to alter the functionality of the radio. This additional hardware could include different user controls (i.e. Function Keys), displays (i.e. 4 digit LED display) and expansion cards (i.e. high speed data). This also means that radios can be upgraded by the user at later date with a upgrade kit.

The following table summarises the products planed:

Variants table

Company	Type	Generation	Display	Controls	Band	Options
	M = Mobile	4 = MK II	0 = None 1 = 4 Digit LED	0 = Rotary Selector 1 = Function Keys 3 = None	5 = US 220MHz 3 = 150-162 MHz	D = High Speed Data L = Built-in Loudspeaker A = Updated variant
LM	M	4	0	0	3	
LM	M	4	0	0	3	L
LM	M	4	0	0	3	D
LM	M	4	0	0	3	DL
LM	M	4	0	3	3	D
LM	M	4	1	1	3	
LM	M	4	1	1	3	A
LM	M	4	1	1	3	D

The LMM4113D is the most fully featured variant of the LMM4000 series of mobile radios and as a result is the subject of this equipment authorisation application. This radio is the most electrically complex variant and incorporates the majority of the additional hardware available for the LMM4000 series.

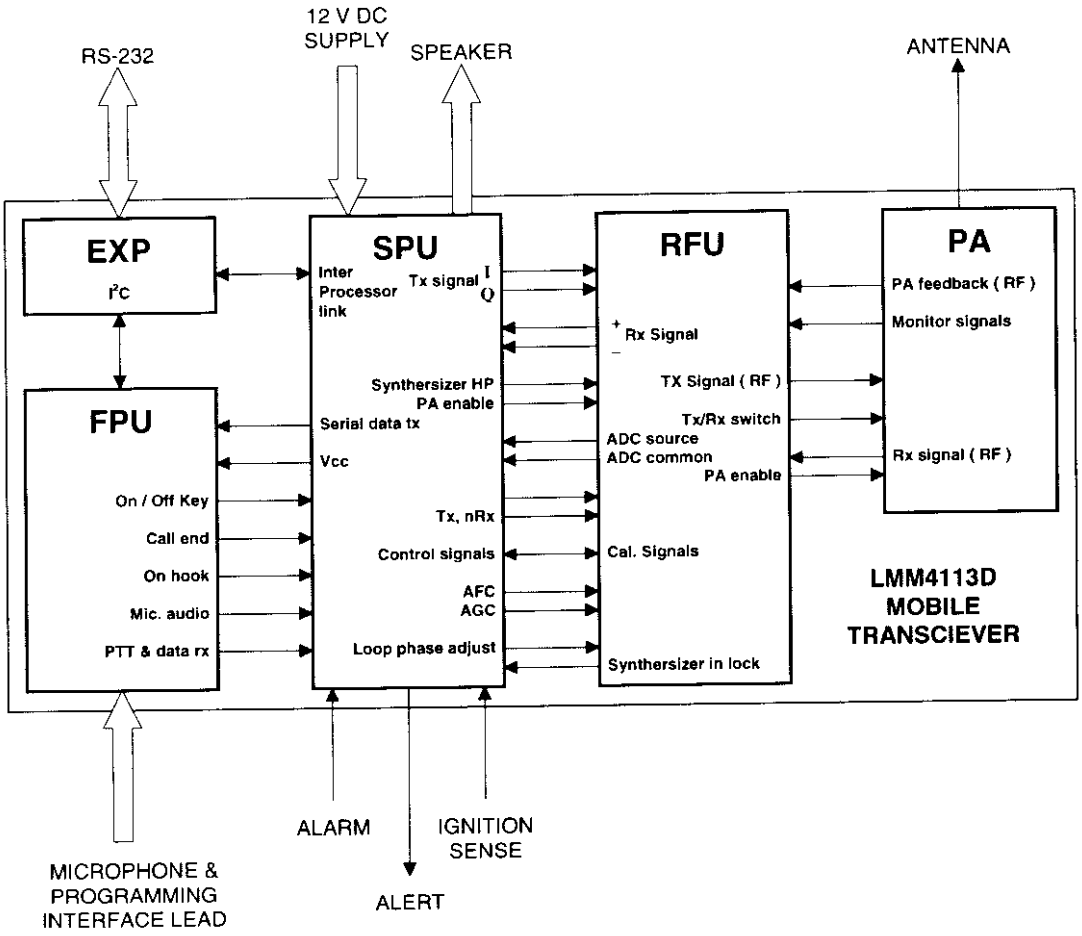
3.3 - Circuit descriptions and block diagrams

The mobile transceiver consists of six main circuits:

- **Front Panel Unit (FPU):** Contains the user interface hardware.
- **Expansion Board (EXP):** Acts as an interface between the data bus on the SPU and the serial I^2C on the FPU and implements processing for high speed data communication (HSD).
- **Signal Processing Unit (SPU):** Which implements the baseband processing for modulation and demodulation.
- **Radio Frequency Unit (RFU):** Which implements conversion to and from radio frequency.
- **Power Amplifier (PA):** Which generates the necessary RF transmit power.

Block Diagram

The following block diagram illustrating the main interconnections between modules:



Front Panel Unit (FPU)

The FPU contains the following user interface hardware.

Microphone Connection

The microphone signal is routed via a 6 way FCC 68 series connector in the base of the FPU to the SPU.

Display

A 4 digit, 7 segment LED Display is used to show various information including called and own idents, status, call time remaining and call set up messages.

Indicator LEDs

Three LEDs are used to indicate the "in service" (IN SERVICE), "call" (CALL) and "transmit" (TX) states.

Keymat

A keymat is provided for controlling the various functions of the mobile radio: On/off, volume, send message, set status code, set ident code, clear stack/calls and alarm.

Expansion Board (EXP)

The Expansion board implements the High Speed Data (HSD) processing and I^2C communication bus between the SPU and user interface.

The EXP has an on board DSP processor (IC2), SRAM (IC3 and 4) and UART (IC8) which is used to perform the signal processing needed to realise High Speed Data communication. The DSP on the EXP communicates with the DSP on the SPU (U102) via a serial link. It also utilises the clock provided by the SPU.

The UART (IC8) generates V24 signals. These signals are converted from TTL levels to V28 levels by IC1. They are then filtered to improve EMC, before connecting to PL1.

A serial communication is provided by an I2C controller (IC9) between the SPU and the user interface (the front interface board and front panel unit). The controller receives data and control signals from the from the SPU via the SPU DSP bus.

Signal Processing Unit (SPU)

The SPU implements the baseband digital signal processing functions required for Reference Vector Equalisation (RVE) and Feed Forward Signal Regeneration (FFSR) channel equalisation. It also performs all control functions for the transceiver including the user interface functions (channel selection, on/off switching etc.) and the trunking protocol management.

The SPU contains the power supply for the transceiver, receiving the vehicle's nominal 12 volt supply, and generating +5V, +9V, +18V and -9V rails from it. The loudspeaker output volume is controlled by the SPU, the audio gain being set from the Front Panel man machine interface.

The SPU is built around a single DSP processor, the TMS320C51 (U102). The main input / output analogue signals (Rx and Tx) are interfaced to the processor by A to Ds and D to As within the CODEC, CS4225-B (U17). The processor has access to ROM and RAM and reads the transceiver personality information from EEPROM, U27. Digital interfacing and glue logic functions are performed by an ASIC (U18).

A six layer board is used, the bottom layer being a RF ground plane. A second ground plane, within the layers, provides a digital, analogue and microphone ground. All analogue signals are screened and guarded.

Power Supply (contained on the SPU PCB)

The power supply unit consists of a switched, charge pump circuit (U6, U7 Q10 and Q11) which produces the +18V and -9V rails, and linear regulators (U3 and U4) for the +9V and +5V rails. The charge pump switching signal, PSU_SYNC is produced by the Gate Array (U18) and is a nominally 102.4 kHz square wave. The charge pump circuit takes the +9V signal output from the linear regulator U4 and doubles it to +18V and mirrors it to -9V. The outputs from the charge pumps are filtered (by L11, C106, C103, C104 etc.) to reduce noise on the output supply.
The vehicle nominal 12 VDC supply is first filtered by L20, C158 and C159 to remove noise then fused by F1 and fed to transient protector D3 which prevents the voltage exceeding 40 V during load dump conditions. D2 protects MOS switch Q3 by preventing the drain to gate voltage exceeding 10 v. The RFU 12V supply (for the PA) is further filtered by L17, C160 and C161 before leaving the board via a feedthrough capacitor.

Radio Frequency Unit (RFU)

The RFU implements conversion to and from radio frequency signals and contains the frequency reference and synthesisers.

The frequency reference provides a local reference for the synthesisers in the mobile. Automatic Frequency Control (AFC) is included to compensate for drift in the local reference. This is controlled by the SPU, which achieves high frequency accuracy by locking to the pilot tone received from the base station.
Programmable synthesisers provide local oscillators for receive and transmit mixing. The synthesisers can be programmed in 2.5 kHz steps.
The receiver down-converts the received signal to a final IF of 12.5 kHz for processing by the SPU. Automatic Gain Control (AGC) is incorporated to accommodate strong signals, and this is controlled by the SPU. The receiver circuit achieves 12 dB SINAD for an input signal of approximately -117 dBm.
The transmitter mixes baseband In-phase and Quadrature signals up to channel frequency and provides pre-amplification. A Cartesian loop circuit is used to linearize a separate power amplifier module. The output power is controlled by the SPU.

Power Amplifier (PA)

The power amplifier accepts the radio frequency drive signal from the RFU and amplifies it to a level suitable for transmission. The circuit also contains a relay for transmit/receive switching and a reverse power level detector. A thermistor is used as a temperature sensor to prevent the PA from overheating.

Full circuit diagrams are contained in Section 3.9

3.4 - (d)(1) Emission types

Emission type (voice modulation)	:	4K00J3E
Emission type (trunking control)	:	4K00J2D
Emission type (user data)	:	4K00J2W

3.5 - (d)(2) Frequency Range

Frequency range (Receive)	:	150.0 to 162.0 MHz
Frequency range (Transmit)	:	150.0 to 162.0 MHz

3.6 - (d)(3) Operating Power Range

Operating power : 25.0 Watts PEP maximum. Variable down to 0.2 Watts PEP.

Output power is adjustable in one of two ways:

1. Power setting during the production process to ensure correct nominal output power.
The output power is adjustable over a range of 20% of nominal power by programming the level into the software. The power level is set once during the production testing and this setting is stored in the radio.

2. Transmission at reduced power in normal operation based on receive signal strength.
Transmit power is reduced under software control when the received signal strength exceeds a preset threshold: i.e. when the mobile is operated in close proximity to a Base station. Power reduction calculation and implementation is performed prior to transmission, and power adjustment is not performed during a transmission over.

3.7 - (d)(4) Maximum Power Rating

Maximum power rating : 25.0 Watts PEP

3.8 - (d)(5) DC Voltage and Current Into Final Amplifying Devices

Method of Measurement

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

Measure Peak Envelope Power (PEP) in a 10 kHz bandwidth. The spectrum analyser is set to maximum hold (span 200 kHz, RBW 10 kHz, VBW 10 kHz, positive peak detector). Measurements are made on the lowest, centre and highest channel frequencies.

Power is calculated according to the equation :

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

P, L and A are defined in the results table below.

Results

DC Current into pin 4 of IC1.

Power level : 25 W PEP nominal
Modulation : Full modulation with 800 Hz and 2100 Hz tones

Frequency	Voltage	Current	Measured Level (L)	Attenuation (A)	Power (P)
(MHz)	(V)	(A)	(dBm)	(dB)	(W)
150.0100	13.8	2.44	14.43	29.51	24.77
156.0000	13.8	2.41	14.46	29.51	24.95
161.9900	13.8	2.53	14.47	29.50	24.95

3.9 - (d)(6) Function of semiconductors and active devices

Front Panel Unit (FPU)

REFERENCE	DESCRIPTION	FUNCTION
IC1	PCF8574	Keypad encoder IC
IC2	SAA1064T	Display driver IC
IC3	SAA1064T	Display Driver IC
IC3, 4, 5, 6, 7	HDSP7801	7 Segment display
D1, 2, 3	BAS16	Keypad decode diode
LED 13	HLMP1440	'IN SERVICE' LED
LED 12	HLMP1340	'TX' LED
LED 11	HLMP1540	'CALL' LED
LED 18, 19, 20, 21, 22, 23, 24, 25	PY1102W	Keymat illumination
LED 22, 25	BR1102W	Keymat illumination

Expansion Board (EXP)

REFERENCE	DESCRIPTION	FUNCTION
IC1	MAX232	RS232 Driver
IC2	TMS320BC52PZA	Digital Signal Processor
IC3	MT5C2568	SRAM
IC4	MT5C2568	SRAM
IC5	P174FCT2245	Bi-directional Buffer
IC6	AM29F010-120JC	Program Storage
IC7	PALCE 16V8H-7JC	I/O and UART interface
IC8	TL16C550A	UART
IC9	PCD8584T	I^2C Bus controller
IC10	74HCT00	Quad NAND gate
IC11	74ACT00	Quad NAND gate
IC12	74HCT00	Delay for I^2C (Non data variant)
IC13	74HCT74	UART clock generation
IC14	74HCT74	Flash bank select
IC15	74HCT74	Delay for I^2C

Signal Processing Unit (SPU)

REFERENCE	DESCRIPTION	FUNCTION
D2	BZX84C10	Protection diode for Q3
D3	LDP24A	Load transient protector
D4	BAS16	ON/OFF control
D5	BAS16	ON/OFF control
D6	ZRA124F01	1.24V Reference voltage
Q1	BC849C	Microphone amplifier
Q2	BC846A	Microphone bias
Q3	RFD15P05SM	ON/OFF switch

REFERENCE	DESCRIPTION	FUNCTION
Q4	BSS84	PSU current driver
Q5	BS170	PSU current driver
Q6	BC846A	DSP reset control
Q7	BC856C	ON/OFF monitor
Q8	BC846A	Power ON/OFF control
Q9	BC846A	Power ON/OFF control
Q10	BSS84	PSU charge pump switch
Q11	BS170	PSU charge pump switch
Q12	BC846A	Audio amp mute control
Q13	BS170	Audio amp mute control
Q14	BC846A	Power ON/OFF control
Q15	BC846A	ON/OFF monitor
U2	TL0741D	Signal amplifier
U3	LM2940T-5.0	5V Voltage regulator
U4	LM2940T-8.0	8V Voltage regulator
U6	SI9952DY	PSU charge pump switch
U7	SI9952DY	PSU charge pump switch
U9	4069U	PSU current driver
U10	39.32160 MHz OSC	DSP clock generator
U12	SN54AS00	Address decoding
U13	MT5C2568	Data memory
U14	MT5C2568	Data memory
U16	27C1001-120	Program memory
U17	CS4225-BL	CODEC
U18	TH4016 100 QFP	ASIC - I/O and clock generation
U23	MAX708	PSU supervisor & reset generator
U24	XC1736	PROM for XC3030
U27	NM93C86A	EEPROM
U28	74HCT4066	Analogue switch
U29	LM2902	Signal amplifier/buffer
U30	TL0741D	Signal amplifier
U101	TDA1519A	Audio amplifier
U102	TMS320BC51PZA	Digital signal processor
U103	74HC14	Hex Inverter
U105	74AC245	Address input latch

Radio Frequency Unit (RFU)

REFERENCE	DESCRIPTION	FUNCTION
D1, 2	BB515	Rx2 LO varactor
D3	ZRA125	Power detector reference
D5, 6	HSMS 2800	Power detector
IC1	SA612A	2nd Rx mixer
IC2	TLC271ID	Rx 2nd IFamplifier
IC3	LMX2332A	Phase Locked Loop IC
IC4	NC7SU04	VCTCXO buffer
IC5	UPB1510GV	RXLO1 divider
IC6	UPB1509GV	RXLO2 divider

REFERENCE	DESCRIPTION	FUNCTION
IC7	TH1088	TX ASIC
IC8	TL071ID	TX Mux buffer
IC9	LMC7101	Power detector buffer
IC10	MAX603ESA	+5V_TX regulator
IC12	78L05	+5V_LO2 regulator
IC13	78L05	+5V_DIV regulator
IC14	78L09	+9V_LO1 regulator
IC15	79L05	-5V regulator
IC16	UPC2713	TXLO buffer
IC17	TK11250	+5V regulator
IC18	74HCT4051	TX multiplexer
TR5	BFS17A	LO2 oscillator
TR6	BFR92A	LO2 buffer
TR7	NE85619	LO1 buffer
TR9	NE85619	RXLO1 buffer
TR1	NE85619	RX amplifier
TR2	BF998	RX mixer
TR3	BF998	RX AGC amplifier
TR4	BC846A	AGC bias
TR11	NE85619	TX amplifier
TR8	BC846A	+5V filter
TR12	BC846A	+5V TX switch
TR15	BCW67A	+5V TX switch
TR13	BC846A	+9V RX switch
TR14	BC856A	+9V RX switch
TR16	BCW67A	+9V RX switch
VCO1A	LVCO2722	VCO module
MX1	TUF-2SM	TXLO mixer
TXC1	NDK5118	10 MHz Crystal VCTCXO

25W Power Amplifier (PA)

REFERENCE	DESCRIPTION	FUNCTION
D1	BAS16	Transmit relay switch protector
D2	BAS16	Driver bias
D3	BZX84CV10	Power supply switch protector
D4	BAR18	Reverse power detector
TR1	BC846A	Transmit relay switch
TR2	BFG235	PA driver amplifier
TR3	BC856A	Driver bias
TR4	BC846A	PA enable switch
TR5	BCW67A	PA enable switch
TR6	BC846A	Power supply switch
TR8	RFD15P05SM	Power supply switch
IC1	M7741H	Power Amplifier module
TH1	PTC Thermistor 2K2 90ºC	Over temperature monitor

3.11 - (d)(9) Tune up procedure

No adjustment is possible on the Radio Frequency Unit or on the Power Amplifier

3.12 - (d)(10) Frequency stabilisation circuitry

The temperature compensated crystal oscillator (TXC0) generates a 10 MHz signal. The frequency of this signal can be adjusted over a limited range by the Automatic Frequency Control (AFC) signal from the SPU. When the mobile transceiver is in receive mode, the SPU locks to a transmitted reference tone from the base station. The reference tone frequency is accurate to within 0.1 ppm (defined by the base station oven controlled crystal oscillator).

When the mobile transceiver is in transmit mode, the SPU holds the AFC level as it was during the last occurrence of receive. The trunking system prevents the transceiver from transmitting unless it has previously obtained a suitable reference from the base station. Thus the frequency of the transmission is always locked to the base reference within the limit of any frequency drift due to temperature variation in the transceiver unit. Frequency variation with time during transmission has been measured and the results are presented in Section 5.8

The combined effect of locking to the base frequency reference and allowing some drift with temperature means that the mobile transceiver frequency accuracy is always much better than 2.0 ppm.

All Local Oscillators within the transceiver are phase locked to the TCX0.

3.13 - (d)(11) Limiting of spurious radiation

Modulation and RF power limiting
Modulation limiting is implemented within the signal processing sub-system. This monitors the output drive to the Cartesian amplifier and reduces the level of the modulating signal if necessary. Detection is achieved using a peak detector in the DSP so that control is based on the output PEP rather than the average power.

The Cartesian amplifier applies power limiting to the RF PA by implementing a feedback loop which generates an error signal based on the difference between the transmitted signal and the amplifier drive signal. The Cartesian loop is a high gain negative feedback system which acts to maintain the output as a good amplified version of the input.

Bandwidth limiting
Within the DSP, the drive signal to the Cartesian amplifier is filtered prior to output. This filter is specified to be tighter than the FCC mask. The Cartesian amplifier then acts to limit the bandwidth of the transmitted signal by reducing power amplifier intermodulation.

Spurious and harmonic limiting
Power supply , control and signal lines are filtered to ensure that unwanted signals do not appear on the transmitter output.

The RF power amplifier is designed for low harmonic distortion. The output of the amplifier is then passed through a seventh order lowpass filter to reduce all harmonics to below the permissible level.