linear modulation technology

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MEMORANDUM

TO: George Tannahill

FCC Application Processing Branch

FROM: Andrew Cunningham
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DATE: 05 August 1999

SUBJECT: Response to questions on pending application

Re: correspondence reference number 8862, date 07/22/1999

FCC ID K7DLMP4213

731 confirmation number EA93897

This document contains 2 sections.

Firstly, the correction to a typographical error in the submission;

secondly, the response to the 5 questions in your correspondence.

I hope that the information given is acceptable.

If you have any further queries please contact me.

Best regards

Andrew

ERRATUM

Page 72 section 5.2 – 2.985(a) RF Output Power

Due to a typographical error, the results table should be replaced with the one given below. The value corrected is– Measured Level at 162.0000 MHz should be 6.11 dBm (not 7 dBm). This is the value recorded at LMT during the formal testing. No other calculations or results are affected by this error. The power indicated (4.80 Watts) was calculated using the correct measured level on the existing submission, and is unchanged.

Frequency	**Measured Level (L)**	**Attenuation (A)**	**Power (P)**
MHz	dBm	dB	Watts
150.0000	6.32	30.6	4.92
156.0000	6.32	30.6	4.92
162.0000	6.11	30.7	4.80

Answers to Questions

Question 1 – bandwidth justification

The modulation process for audio and data signals is described in the answer to Question 3.

The modulation schemes for voice and data are identical to those used on the K7DLMP4215 220 MHz Handportable radio and K7DLMM4113D 150 – 162 MHz mobile radio. The modulation scheme is designed for operation in 4 kHz occupied bandwidth such as that allowed on the 220 MHz band, and is suitable for use in 6 kHz occupied bandwidth systems in the 150 – 162 MHz band .

Voice
Voice signals with an audio spectrum of 300 Hz to 3 kHz are modulated onto an RF pilot signal using TTIB techniques, which includes a additional band of 600 Hz. This gives a resultant RF bandwidth of 2700 Hz + 600 Hz = 3300 Hz.
A bandwidth designator of 4 kHz is sought.

TTIB is a form of pilot aided single sideband modulation.
A modulation designator of J3E is sought – suppressed carrier single sideband modulation, analogue modulation, voice transmission.

Data
Incoming data signals at up to 19,200 bit/s are buffered to a rate of 1200 bit/s and are fed into the DSP based FFSK modulator, from which point they follow the same modulation process as the audio signals. The occupied RF bandwidth will thus not exceed 3300 Hz, and a bandwidth designator of 4 kHz is sought.

The data signal is FFSK modulated and then passed through the TTIB modulation process.
A modulation designator of J2D is sought – suppressed carrier single sideband modulation, digital signal– modulated subcarrier analogue modulation, data transmission.

Question 2 – user manual mentions high speed data

The 75-P4213 handportable does not support high speed data and this is explicitly stated on p33 of the User Manual (p62 of the submission).

The user manual mentions a higher data rate on p12 (page 41 of the submission). This is describing the general performance of the LM system environment in which the handportable radio would operate, which consists also of mobile radios and base repeater channels; the K7DLMM4113D mobile radio and K7DLMC4003 base repeater both support 14.4 kb/s data.

Question 3 – description of signal parameters, modulation technique, signal path for data signal.

LINEAR MODULATION

Definition

Linear Modulation (LM) is a Radio Frequency (RF) transmission technique suitable for the transfer of speech and high speed data over a radio bearer which is **narrow band**. In this context narrow band is a 5 kHz bandwidth radio channel.

The speech quality over 5 kHz channel using LM techniques is equal to, or better than that achieved from a 12.5 kHz channel using Frequency Modulation. Also adjacent and co-channel performance easily exceeds that specified for 12.5 kHz channels and is in excess of that specified for narrow band systems both by the DTI in the United Kingdom and the FCC in the United States.

Note also that for Linear Modulation systems, significant energy is only transmitted when the transmitter is modulated. This is similar to Single Side Band operation but is unlike Frequency Modulated transmissions, which operate constant envelope. This fact provides a lower power consumption for LM equipment when compared to AM or FM equipment which is particularly important for the sizing of standby power systems and for hand-portable units.

LM Methods

Linear Modulation uses a number of methods to achieve this high quality performance. These are the use of a **Transparent Tone In Band (TTIB)** reference signal**, Feed Forward Signal Regeneration (FFSR)** for signal recovery and **Cartesian loop** linearisation of the RF transmitter**.**

For the TTIB technique, the audio baseband is split at 1650 Hz to give an upper and lower sub-band, and the two sub-bands are moved apart in frequency to form a gap. A calibrated pilot tone is then inserted in this gap. The resulting signal is then linearly translated up to RF using a direct conversion quadrature transmitter, so that the pilot tone falls on the channel centre. A frequency inversion also takes place during this process.

In the receiver, FFSR is used to correct for Doppler shift and multipath distortions which affect signals when transmitted in mobile environments. The distortions on the path are calculated from the received pilot tone, and the whole audio band is then corrected for these distortions. The two halves of the audio band are then inverted and rejoined to give the recovered audio signal.

The Cartesian loop process linearises the transmitter and minimises radiation into adjacent and near channels.

Basic Operation

The audio signal derived from the users microphone is processed to insert a reference signal in the transmission. This reference is used at the receiver to define the compensation to the received signal necessary to overcome the amplitude, frequency and phase distortion caused by the radio path. The manipulation required to achieve this and the use of very linear RF transmitters allows the signal to be contained within a 5 kHz radio channel.

Data Signal Modulation

Incoming data signals at up to 19,200 bit/sec are buffered to give a 1200 bit/sec rate for transmission and are passed into the DSP where a software implementation of an FFSK modulator is used. The effective modulating tones are at 750Hz and 1350 Hz, generated in complex baseband format. These are used instead of the standard 1200 Hz and 1800 Hz tones; the offset of 450 Hz is used to place all the energy in one transmitted sub-band to avoid the need for phase locking of the received signal.

The modulated data signal now proceeds to the TTIB modulation process, replacing the audio signal in the description below.

Transmission Techniques

The transmission process takes the form of splitting the microphone audio signal, which has an audio spectrum between 300 Hz and 3000 Hz, into two sub-bands, inserting a pilot tone between the two sub-bands and then using the audio signal to modulate the RF.
The splitting process and the tone insertion occurs in a Digital Signal Processor (DSP). The analog signal from the microphone is first passed through an analog to digital (A to D) converter and then input to the DSP. The DSP can perform manipulations to the signal in the digital domain which are not possible in the analog domain — for example, the use of negative frequencies. Internally the DSP represents the audio signal not simply as the digital stream derived from the A to D converter but as a complex quantity in Cartesian form (e.g. the instantaneous value at any point in time is not defined by amplitude and phase but by a Cartesian co-ordinate value using *I* and *Q* axes, which represent the instantaneous amplitude and phase).

The dynamic amplitude and phase of the RF signal needs to be known and controlled.
Definition of a signal in terms of phase and amplitude is possible but it is easier to handle the signals in terms of a co-ordinate system, hence the Cartesian or I and Q description.
This is made a practical proposition if the manipulation is in the digital domain.

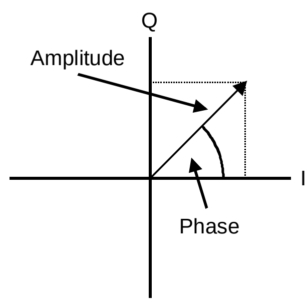

Figure 1–1

It also takes the all positive 300 to 3000 Hz input audio signal, and places it symmetrically about a nominal DC (0 Hz) point. The audio range is now -1350 Hz to +1350 Hz.
The manipulation from the input audio signal to two audio sub-bands is shown in Figure 1–4.

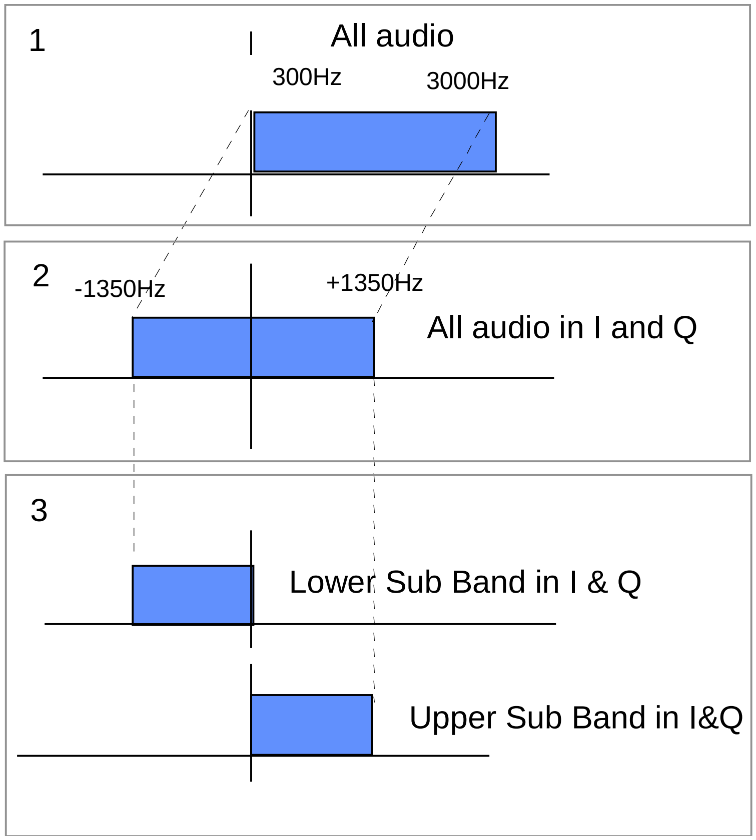

Figure 1–2

Having placed the audio signal around a defined point (0 Hz), the DSP now splits the negative portion away from the positive portion as two sub-bands, the lower sub-band holding the information derived from the microphone in the 300 Hz to 1650 Hz spectrum the upper sub-band containing the remaining 1650 Hz to 3000 Hz information.

The two sub-bands are then 'moved apart' leaving a guard band between the upper and lower sub-bands (Figure 1–3).

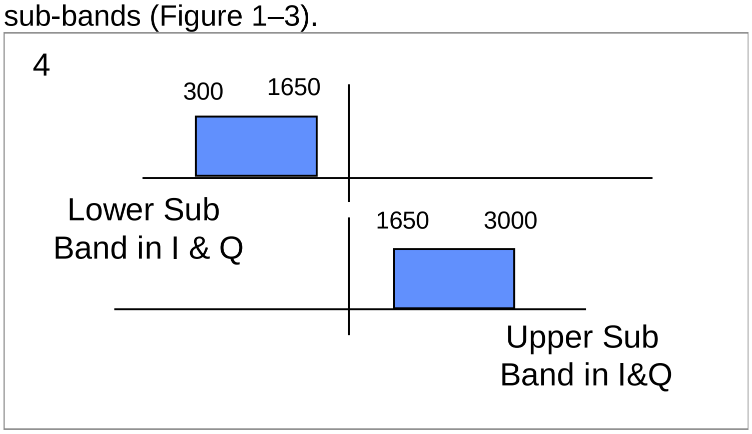

Figure 1–3

The DSP inserts a tone of 1950 Hz into the centre point of the guard band. (Figure 1–4).

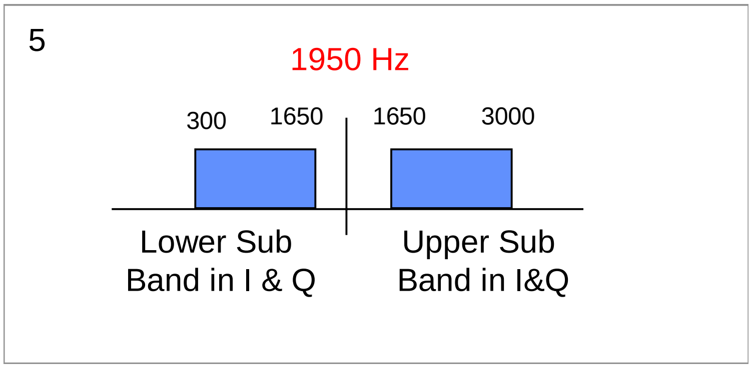

Figure 1–4

The tone is in the audio band but due to the DSP processes on the transmit and receive paths, it is inaudible (transparent) to the user, hence the description: **Transparent Tone In Band (TTIB)**.

The modulation process is a direct one — the digital audio from the DSP is fed through a digital to analog (D to A) converter and into the modulator where it is converted directly to the final radio frequency. The process inverts the two sub-bands so that the upper audio band appears in the lower RF sub-band and *vice versa*. (Figure 1–5).

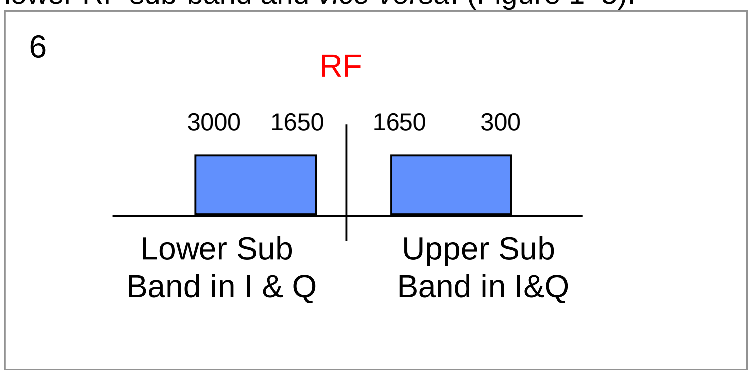

Figure 1–5

The transmission does have a vestigial carrier. The TTIB tone and the carrier occupy the same point in the RF transmission.

The transmitter is a simple amplifier with no mixing stages.

Cartesian Loop Linearisation of the Transmitter

To ensure that the transmitter is linear and that signals do not suffer from a non-linear transposition from audio to RF, a linearisation technique is applied to the transmitter. This is achieved by the use of a **Cartesian Loop Transmitter (CLT).**

The **Cartesian Loop Transmitter (CLT)** uses an RF 'sniffer' to provide a sample of the outgoing transmission. This is fed back to an RF demodulator which produces two outputs in Cartesian form — *I* and *Q* (hence Cartesian Loop feedback). These are compared with the values of the *I* and *Q* inputs to the modulator and any variation compensated for. This feedback regime produces a very linear RF transmitter with high efficiency.

Question 4 – sample calculation of power output measurement

Section 5.2 2.985(a) RF Output power

Example used RF output power at 156.0000 MHz.

A 2 tone test signal is used, giving a spectrum which consists of 2 tones of equal level, and a pilot signal approximately 4 dB below this. All the signal energy is contained within a 2 kHz bandwidth.

The spectrum analyser is set to give a resolution bandwidth of 10 kHz – this is wide enough to contain the total energy of the signal. Using the peak hold function ensures that the Peak Envelope Power of the signal is measured.

Measured level of signal is 6.32 dBm (this value is taken for L)

The measured insertion loss is 30.6 dB (this value is taken for A)

The output power is calculated as

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

$P = 10^{(36.92/10 - 3)}$

$P = 10^{(3.692-3)}$

$P = 10^{(0.692)}$

P = 4.92 Watts

Question 5 – multiple insertion loss and return loss plots

Page 73

The plots are for the RF attenuator presented to the transmitter for RF power measurements

Pages 81,82,83

Measurements performed for Section 5.6 – 2.991 / 90.210(e) Spurious emissions at antenna terminal.

The RF load plots have been performed for the 2 different equipment set-ups: measurements close to the carrier use only an attenuator after the transmitter; measurements of transmitter harmonics and other far out products require the use of a notch filter to remove the fundamental transmitted signal and avoid overloading the spectrum analyser.

The plots are as follows:

RF load for spurious less than 250 kHz offset : attenuator and cables –insertion loss and return loss - wide band.

RF load for spurious greater than 250 kHz offset : attenuator plus notch filter and cables –insertion loss and return loss - wide band.

RF load for spurious greater than 250 kHz offset : attenuator plus notch filter and cables –insertion loss and return loss – narrow band showing the presence of the notch.