THOMCAST
COMMUNICATIONS Inc.
COMWAVE DIVISION

PO Box 69, 395 Oakhill Road, Mountaintop, PA 18707;
570-474-6751; FAX 570-474-5469

To Whom It May Concern:

When I submitted the test report for this transmitter I sent the wrong file. Please disregard the first file that was sent to you and use this as the test report.

Thank you,

Kimberly Simeone

Kimberly Simeone
Technical Writer

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FCC CERTIFICATION REPORT

FOR THE

<u>SD2500, 25 WATT DIGITAL TRANSMITTER SYSTEM</u>

THOMCAST COMMUNICATIONS,
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TABLE OF CONTENTS

TABLE OF FIGURES

TABLE OF PLOTS

TABLE OF TABLES

PO Box 69, 395 Oakhill Road, Mountaintop, PA 18707;
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1.0 INTRODUCTION

This report contains all the required data for certification of Thomcast's model SD2500 digital transmitter system. The data presented was taken from tests performed on a production transmitter system tuned to operate on ITFS channel G-4 (2680-2686 MHz) designed to transmit any one of 31 ITFS/MMDS television channels, in the MDS and ITFS bands. Other information required for Certification, such as circuit diagrams and descriptions, photographs, and tune-up and maintenance procedures may be found in the technical manual, which is attached.

2.0 TEST EQUIPMENT

FCC Section 2.947 (d)

The following is a list of major test equipment, which was used in testing the transmitter for this report:

1)	Spectrum Analyzer	HP Model 8564E & 8593E
2)	Power Meter	HP Model 436A
3)	Frequency Counter	HP Model 5350B
4)	Digital Multimeter	Fluke Model 87
5)	Vector Signal Analyzer	HP 89441A
6)	Digital Transmission Analyzer	HP 3784A

3.0 MEASUREMENTS

FCC Section 2.1033 (c)(14)

➢ RF POWER OUTPUT

FCC Section 2.1046 (a) (c)

Output Power: 25 watts average

Method of Measurement: Per FCC 2.1046 (b)

The transmitter was operated into a dummy load of substantially zero reactance with a resistance equal to the transmission line characteristic impedance. Average power was directly measured using an HP 436A microwave power meter. The transmitter's % power meter was found to be within 2% of the indications provided by the external average power meter with output variations of 80% to 110% of the transmitter's rated output.

Output Power Calibration: See technical manual, document # DOC16-0003

➢ MODULATION CHARACTERISTICS

FCC Section 2.1047

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The digital modulation format is Quadrature Amplitude Modulation with a 64 or 256 point signal constellation (64 QAM and 256 QAM) with the QAM symbol rate and occupied bandwidth optimized for a 6 MHz channel plan. Forward Error Correction (FEC) uses a concatenated coding approach that produces high coding gain at moderate complexity and overhead. The system FEC is optimized for quasi-error free operation at a threshold output error event rate of one error per 15 minutes.

To achieve the appropriate level of error protection required for transmission of digital data, an FEC based on Reed-Solomon coding is used. Protection against burst errors is achieved by use of byte interleaving.

The digital input stream is organized in fixed length packets following the MPEG-2 transport multiplexer. To ensure adequate binary transitions for clock recovery, the data at the MPEG-2 transport multiplexer output is randomized according to the Pseudo Random Binary Sequence (PRBS) generator. The randomization process is also active when the modulator input bit stream is non-existent, or when it is non-compliant with the MPEG-2 transport stream format. This avoids emission of an unmodulated carrier from the modulator.

Following the energy dispersal randomization process, systematic shortened Reed-Solomon encoding is performed on each randomized MPEG-2 transport packet with T=8. This means that 8 erroneous bytes per transport packet can be corrected. This process adds 16 parity bytes to the MPEG-2 transport packet to give a codeword.

Convolutional interleaving with depth I=12 is applied to error protected packets. This results in an interleaved frame. The convolutional interleaving process is based on the Forney approach, which is compatible with the Ramsey type III approach. The interleave frame is composed of overlapping error protected packets and is delimited by MPEG-2 sync bytes.

After convolutional interleaving, an exact mapping of bytes into symbols is performed. The mapping relies on the use of byte boundaries in the modulation system. The two most significant bits of each symbol are differentially encoded in order to obtain a p/2 rotation-invariant QAM constellation.

Digital modulation adheres to Quadrature Amplitude Modulation with 64 points in the constellation diagram. Constellation points in Quadrant 1 are converted to Quadrants 2, 3 and 4 by changing the two MS (I_k and Q_k) and by rotating the qLSBs according to the following table.

Table 1: Quadrant Conversion Constellation.

Quadrant	*MSBs*	*LSBs rotation*
1	00	
2	10	$+\pi/2$
3	11	$+\pi$
4	01	$+3\pi/2$

64-QAM

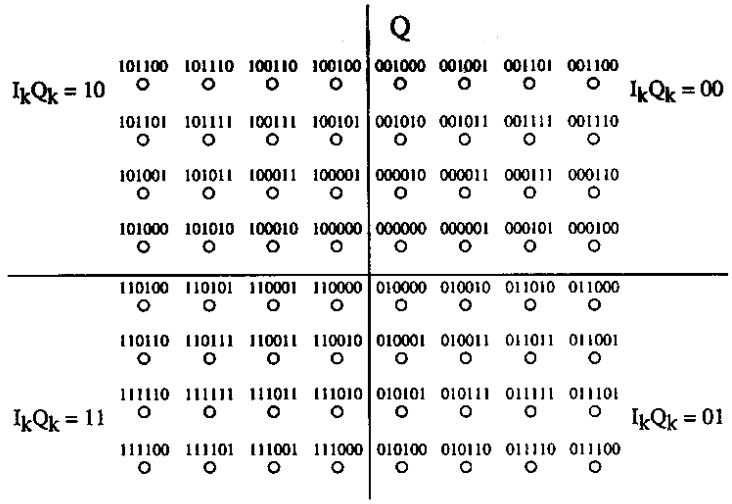

Figure 1: 64-QAM Constellation Diagram.

The MMDS digital modulation format is summarized in the following table:

Table 2: MMDS Digital Transmission Format.

Parameter	*Format*
Modulation	64/256 QAM rotationally-invariant coding
Symbol Size	6 bits, 3-bits for “I” and 3 bits for “Q” dimension or 8 bits, 4-bits for “I” and 4 bits for “Q” dimension
Transmission Band	2000 - 2700 MHz
Channel Spacing	6 MHz
Symbol Rate	5.056944 Msps ±3 ppm or 5.06380 Msps ± 3 ppm
Frequency Response	Square-root raised-cosine filter: Roll-off = 0.18 or 0.15

Table 3: 64/256 QAM Modulator RF Output.

I/Q Phase Offset	< 1.0 degrees
I/Q Crosstalk	≥-50 dB
I/Q Amplitude Imbalance	0.05 dB max
I/Q Timing Skew	< 3.0 ns

Modulator Baseband Filtering:

Prior to modulation, the I and Q signals shall be square-root raised-cosine filtered. The roll-off factor shall be 0.15 or 0.18 depending upon modulator symbol rate.

The square-root raised cosine filter shall have a theoretical function defined by the following expression:

$$H(f) = 1 \text{ for } |f| < f_N(1-\alpha)$$

$$H(f) = \sqrt{\frac{1}{2} + \frac{1}{2}\sin\frac{\pi}{2 f_N}\left[\frac{f_N - |f|}{\alpha}\right]} \quad \text{for } f_N(1-\alpha) \le |f| \le f_N(1+\alpha)$$

Where:

$$f_N = \frac{1}{2T_S} = \frac{R_S}{2}$$ is the Nyquist frequency and rolloff factor $\alpha = 0.15$ or 0.18

The value of in-band ripple r_m in the pass-band up to $(1-\alpha) f_N$ as well as at the Nyquist frequency f_N shall be lower than 0.4 dB. The out-of-band rejection shall be greater than 43 dB after the first upconversion.

The filter shall be phase-linear with the group delay ripple $\le 0.1\ T_S$ (Ns) up to f_N where $T_S = 1/R_S$ is the symbol period.

Modulation Channel Occupancy:

The digital modulation occupancy of 64/256 QAM is 5.38 MHz measured at the -3 dB roll-off points. This is shown below as compared to a standard NTSC vestigial sideband signal in a standard 6 MHz channel. The 64/256 QAM signal employs a suppressed carrier modulation with a uniform power spectral density as opposed to the usual PAL M / NTSC signal with separate analog, visual, chroma, and aural carriers.

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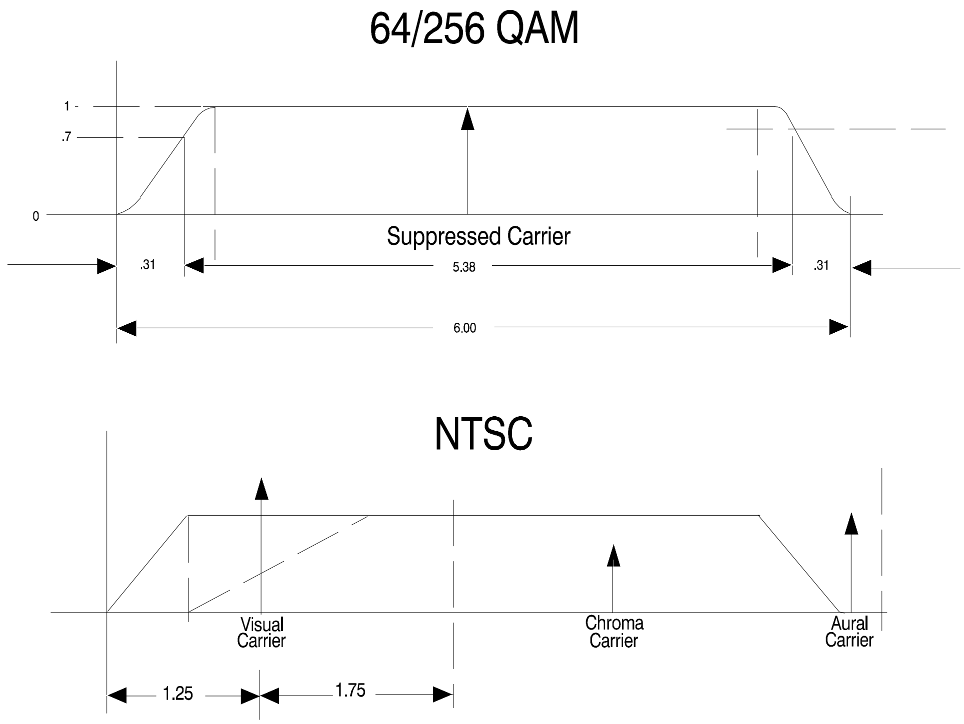

Figure 2: Digital modulation occupancy.

The following plot shows the demodulated performance of the 64 QAM transmitter as measured with an HP89441A Vector Signal Analyzer.

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Date: 11-23-99 Time: 08:36

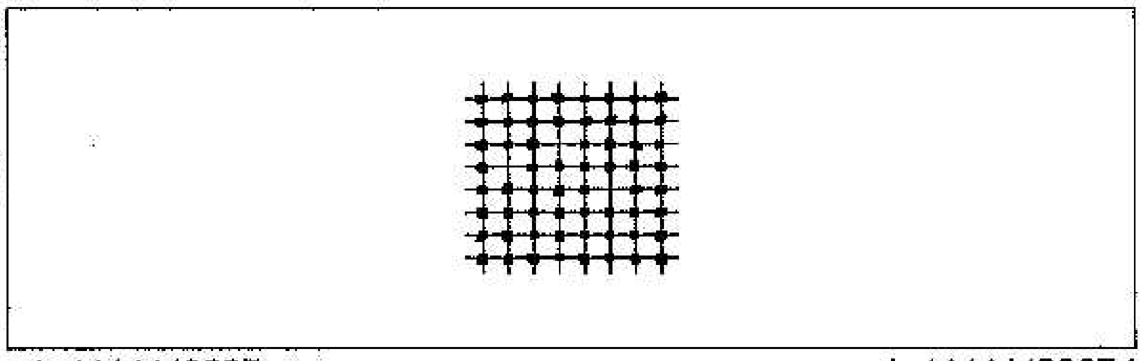
TRACE A: Ch1 64QAM Meas Time CW____ CH____ SER____ MODEL____

1.5

Const

300
m
/div

-1.5



-4.4444442987 4.44444429874

TRACE B: Ch1 64QAM Syms/Errs UNEQUALIZED

EVM	= 945.64	m%rms	1.9093	% pk at sym	159		
Mag Err	= 667.29	m%rms	1.5563	% pk at sym	121		
Phase Err	= 966.92	mdeg	5.3565	deg pk at sym	109		
Freq Err	= 17.470	Hz					
IQ Offset	= -59.631	dB	SNR (MER)	= 36.824	dB		

0	01011110	11000011	10000100	10111010	10111101	01011111
48	01100011	10001101	00011001	11101100	10001001	00100000
96	10001101	01010100	01101100	00111010	00000001	01000000
144	00111010	10000100	01010001	11100100	11110010	00111000
192	10011100	00000101	01100101	01011100	01001100	00000000
240	01010101	01110011	00101111	01000001	10100000	10111110
288	11100011	10011110	11110111	01101101	00101111	01011101
336	11000000	11110100	11010110	11100011	01100010	11011011

PLOT 1: Demodulation performance of the 64 QAM transmitter.

- GROUP DELAY

FCC Section 73.687 (a) (3)

Output Power:	25 watts average
% Video Modulation:	Not applicable
Type Video Modulation:	Not applicable
Aural Output Power:	Not applicable
Method of Measurement:	Per EIA RS-240, Section B (12c)

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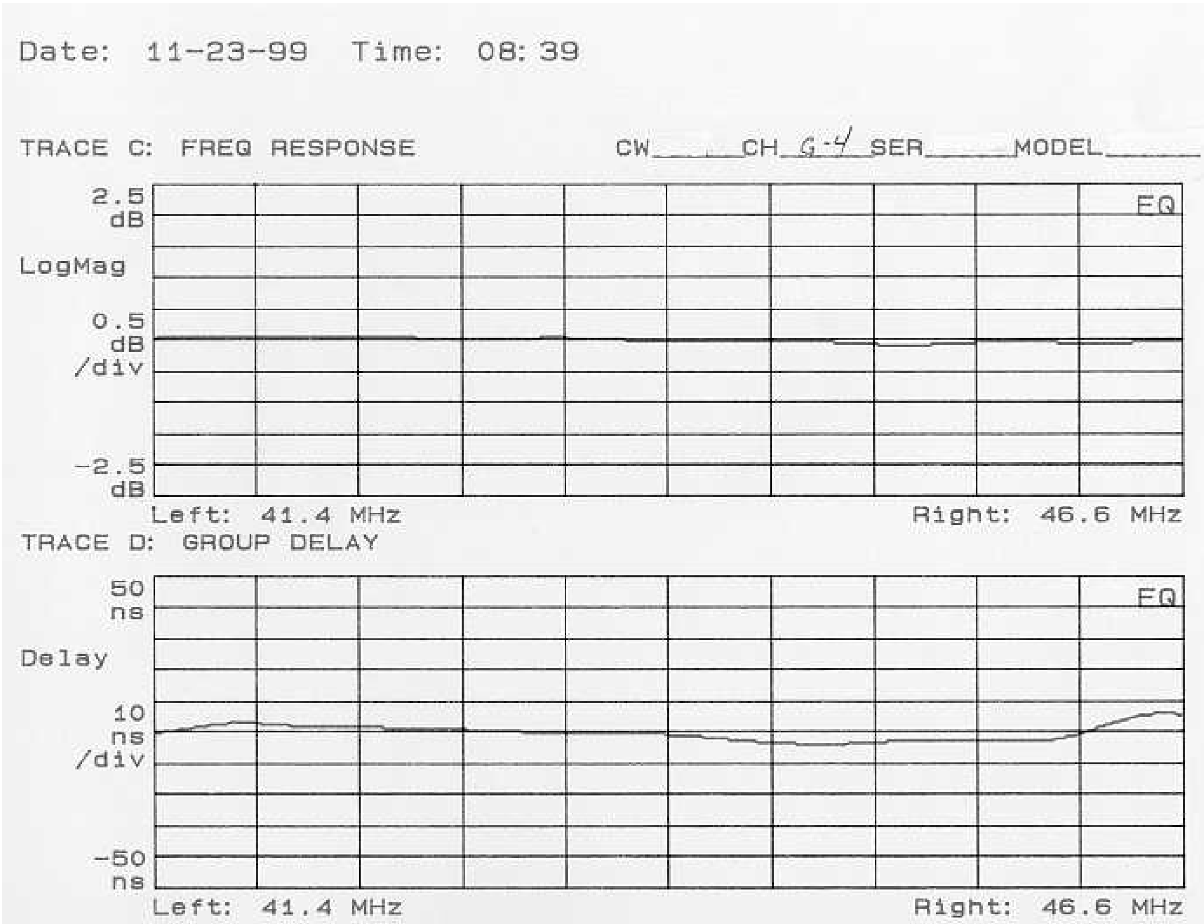

PLOT 2: Frequency response and group delay.

- OCCUPIED BANDWIDTH & FREQUENCY RESPONSE
  FCC Section 2.1049 (e) (6) (i)

See the above plot for frequency response data.

- OCCUPIED BANDWIDTH
  FCC Section 2.1047/2.1049/73.687 (a) (2)/74.936

The following plot demonstrates the occupied bandwidth of the QAM signal at the output of the system channel combiner at the maximum rated average power and symbol rate. The occupied bandwidth complies with the revised spectral mask per the FCC ruling. The signal meets the requirements of a sidelobe power sprectral density less than –38 dB at the channel edge decreasing to less than –60 dB at ±3 MHz from the channel edge relative to the average power spectral density of the QAM signal within the main channel. Each occupied bandwidth plot is labeled in the lower right corner corresponding to the respective QAM.

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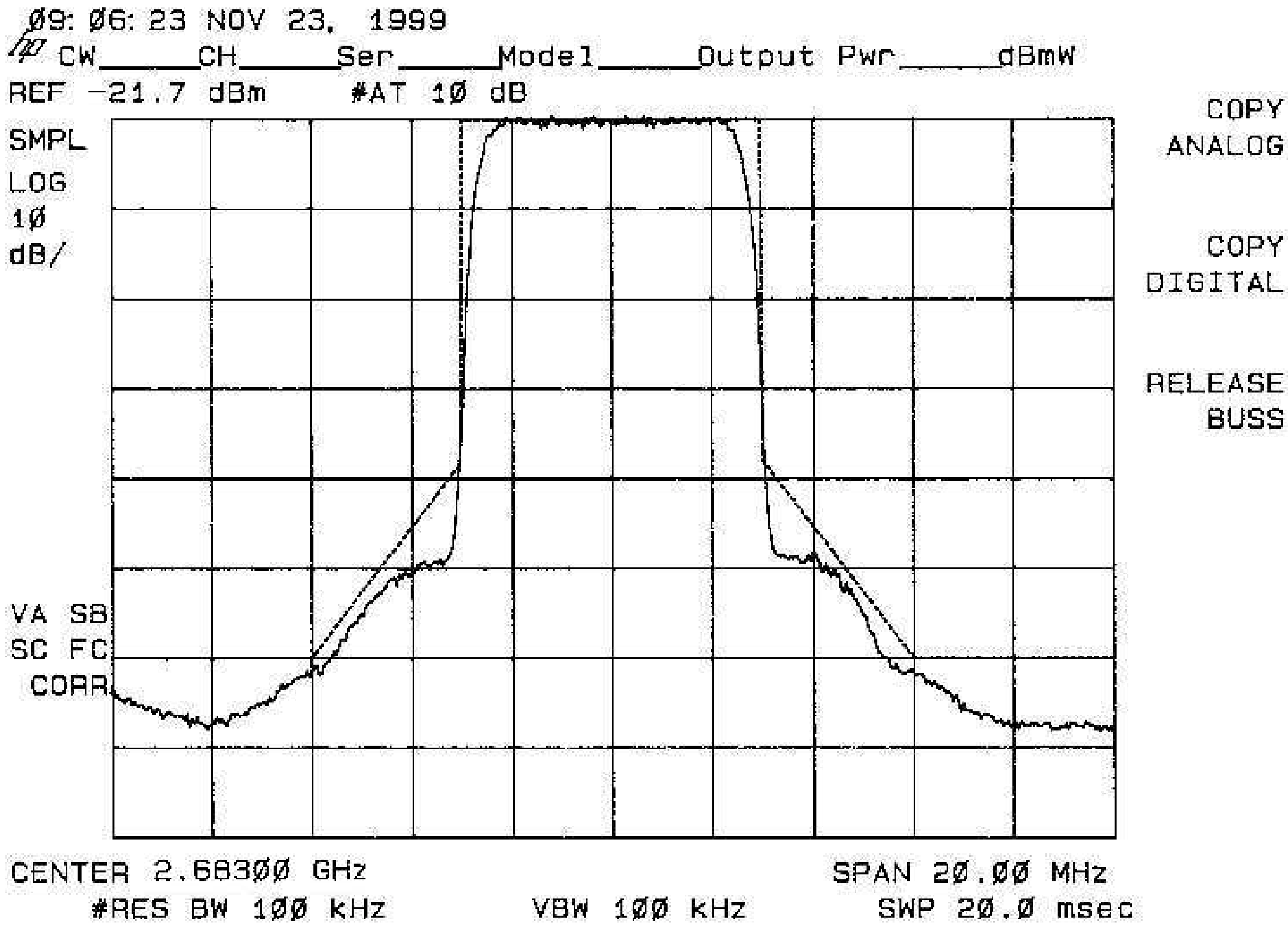

PLOT 3: Occupied bandwidth.

❖ <u>SPURIOUS EMISSIONS AT ANTENNA TERMINALS</u>
FCC Section 2.1051/2.1057/21.908 (b)/74.936

Average Output Power:	25 watts
Type Modulation:	64/256 QAM
Spectrum Analyzer Setting:	The Spectrum Analyzer setting used in conducting the spurious emissions test at the equipment output terminals was as follows

Frequency Span:	2 MHz per Division
Center Frequency:	Adjusted continuously for 10 MHz to 27 GHz
Resolution Bandwidth:	100 KHz
Video Filter:	Out

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Input Attenuator Setting: Input level was set for a full-scale calibration of the average digital power. All other frequencies were referenced to this point.

Spurious Emissions: See chart

Table 4: Spurious emissions.

Frequency (MHz)	Amplitude (dBc)	
2683.00	0	Carrier Reference
2727.00	-69	Local Oscillator
5366.00	<-70	2nd Harmonic
8049.00	<-70	3rd Harmonic
10732.00	<-70	4th Harmonic
13415.00	<-70	5th Harmonic
16098.00	<-70	6th Harmonic
18781.00	<-70	7th Harmonic
21464.00	<-70	8th Harmonic
24147.00	<-70	9th Harmonic
26830.00	<-70	10th Harmonic

No other spurious emissions detected.

❖ FIELD STRENGTH OF SPURIOUS RADIATION
FCC Section 2.1053, 2.1057

Average Output Power: 25 watts

Type Modulation: 64/256 QAM

Spectrum Analyzer Settings: A spectrum analyzer used to measure the spurious emissions at a distance of 10 meters from the transmitter was set as follows:

Frequency Span: 1 MHz per division
Center Frequency: Adjusted continuously from 10 MHz to 10 GHz
Resolution Bandwidth: 100 KHz
Video Bandwidth: 100 KHz
Analyzer Noise Threshold: <-90 dBm

Method of Measurement:

Absolute power of the spurious radiation was measured on a spectrum analyzer at a distance of 10 meters from the transmitter. The radiation was received with a half-wave dipole antenna (gain = 2.15 dB) and measured as an absolute power level; therefore, all measurements include the dipole gain. The relative levels of the received spurious signals

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were calculated with respect to the absolute power level of the transmitter's output received with a dipole at 10 meters. The received power level was calculated using:

Received @ 10 meters (dBm) = EIRP (dBm) - Path Loss (dB) + 2.15 dB

Path Loss (dB) = 20 log distance(Km) + 20 log frequency (center frequency 2.683)(GHz) + 92.4 dB
= 20 log (.010 Km) + 20 log (2.683) +92.4 dB
= 60.97 dB

EIRP (dBm) = 44 dBm (tx output) + 2.15dB (transmit dipole gain)
= 46.15dBm

Received Level = **EIRP** dBm - **Path Loss** dB + 2.15 dB
= -12.67dBm

The Electric Field Intensity E(v/m) incident on a receive dipole antenna was found using:

$$E\ (v/m) = \text{Antilog}\left[\frac{(\text{Received Level} - 2.15\ dB) - 20 \log \text{wavelength}(m) + 6.75}{20}\right]$$

$$= \text{Antilog}\left[\frac{-12.67\ dBm - 2.15\ dB - 20 \log [0.111815132\ m] + 6.75}{20}\right]$$

= Antilog 0.5479

E = 3.531 v/m

Spurious Radiation:

The following measurements of radiation were taken and are given in terms of absolute and relative dBm to the average digital signal power.

Table 5: Spurious Products/Harmonics Field Measurements.

	Absolute Received (dBm)	Absolute Field Intensity (v/m)	Relative to Level (dBm)
10.00 MHz	*Below analyzer threshold	N/A	<-90
44 MHz	*Below analyzer threshold	N/A	<-90
2727 MHz	*Below analyzer threshold	N/A	<-90
Harmonics	*Below analyzer threshold	N/A	<-90
Sub-Harmonics	*Below analyzer threshold	N/A	<-90

* Analyzer threshold = -90 dBm

Analyzer Settings:

Reference Level:	-20 dBm
RBW:	100 KHz

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Video Average:	ON
Attenuation:	10 dB
Span:	5 MHz

❖ FREQUENCY STABILITY
FCC Section 2.1055 (a) (1) / 73.687 / 21.101 (a)

Method of Measurement: The upconverter was Channel tested per FCC Part 73, Subpart E, Section IV (c)

Microwave L.O. (Synthesized)	2727.00 MHz
IF Frequency (Modulator*)	- 44.00 MHz
On Channel Frequency	2683.00 MHz

**Modulator is certified separately.*

Frequency Stability over Temperature: **Phase Locked Oscillator**

Table 6: Frequency stability over temperature.

Temperature	Frequency (GHz)	Error (Hz)
+25	2.727000000	0
-30	2.726999988	-12
-20	2.726999986	-14
-10	2.726999982	-18
0	2.726999978	-22
+10	2.726999974	-26
+20	2.726999972	-28
+30	2.726999993	-7
+40	2.726999969	-31
+50	2.726999965	-35

Frequency Stability over AC Input Voltage: **Phase Locked Oscillator**

Table 7: Frequency stability over AC input voltage.

AC Line (V)	LO Frequency (MHz)
95	2.727000008
100	2.727000008
110	2.727000009
115	2.727000009
120	2.727000009
125	2.727000009
130	2.727000008
135	2.727000009

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NOTE:
Frequency stability of the microwave LO was totally dependent on the accuracy and stability of the 10 MHz reference oscillator. This is a purchased item with ±2 x 10^{-8} stability over temperature range.

4.0 SUMMARY

This report demonstrates that the SD2500 digital television transmitter meets or exceeds the FCC certification criteria. The output power was verified with direct measurement of power at microwave. The digital modulation format specified is based upon Quadrature Amplitude Modulation with a 64 or 256 point signal constellation. The occupied bandwidth conforms to the required digital spectral mask with –38 dB emissions at the channel edges and a constant slope attenuation from this level to –60 dB ±3 MHz extending into the adjacent channels. Measurement of spurious emissions at the RF output revealed no emissions above -60 dBc. Field strength measurements of spurious emissions revealed no detectable emissions down to the analyzer noise threshold of < - 90 dBm. Frequency stability tests of the phase locked crystal oscillator over variations in temperature or input AC line voltage showed a maximum worst case frequency shift of 35 hertz.