FCC CERTIFICATION REPORT

FOR THE

SDA2500C, 25 WATT FREQUENCY AGILE DIGITAL TRANSMITTER SYSTEM

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TABLE OF CONTENTS

TABLE OF FIGURES

TABLE OF PLOTS

TABLE OF TABLES

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1.0 INTRODUCTION

This report contains all the required data for certification of Thomcast's model SDA2500C frequency agile 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, tune-up and maintenance procedures, and the technical manual are 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 QAM modulation; 20 watts average QAM modulation with three equally spaced 2 MHz carriers

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 # DOC16-0061

➢ MODULATION CHARACTERISTICS

FCC Section 2.1047

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.

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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	$+3\pi/2$

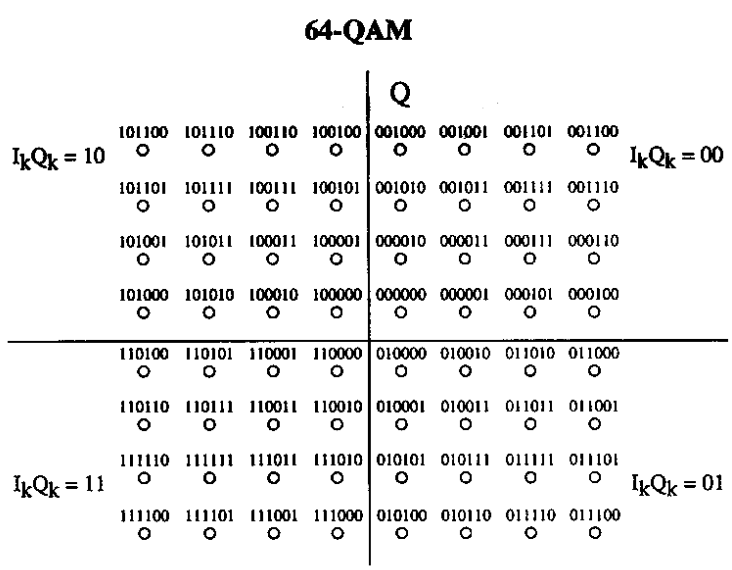

Figure 1: 64-QAM Constellation Diagram.

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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:

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

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

Where:

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

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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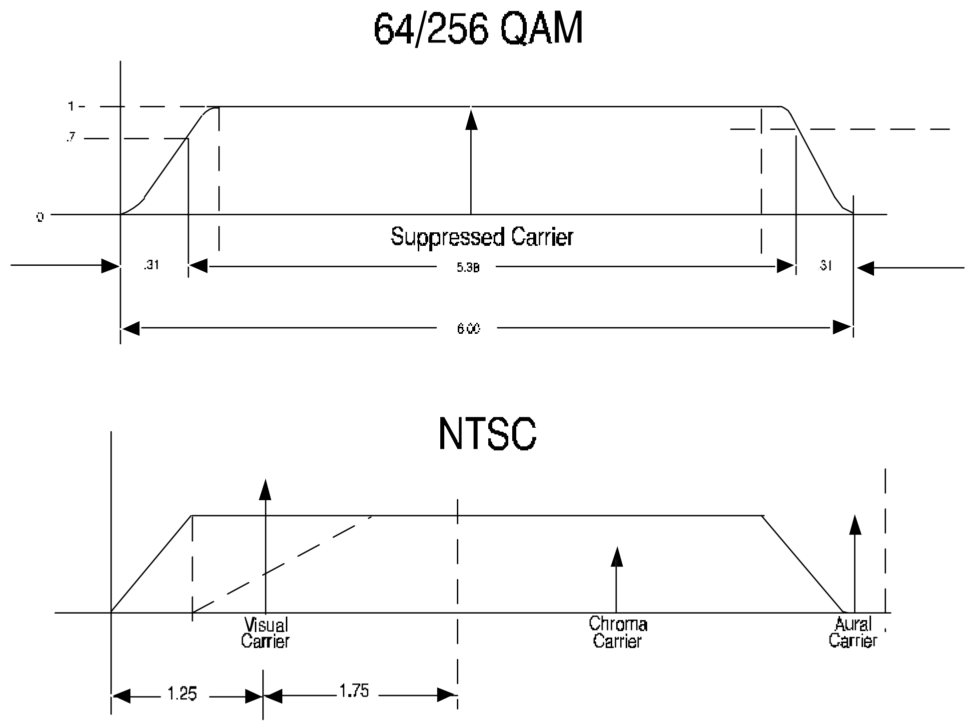

Figure 2: Digital modulation occupancy.

Plot one and two show the demodulated performance of the transmitter as measured with an HP89441A Vector Signal Analyzer.

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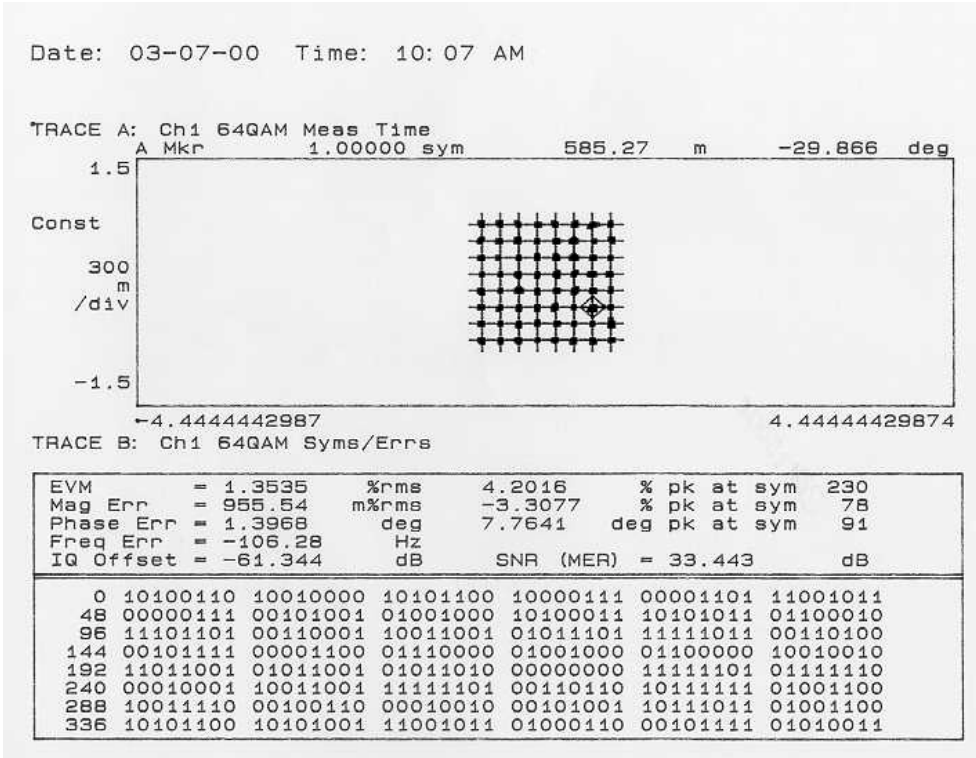
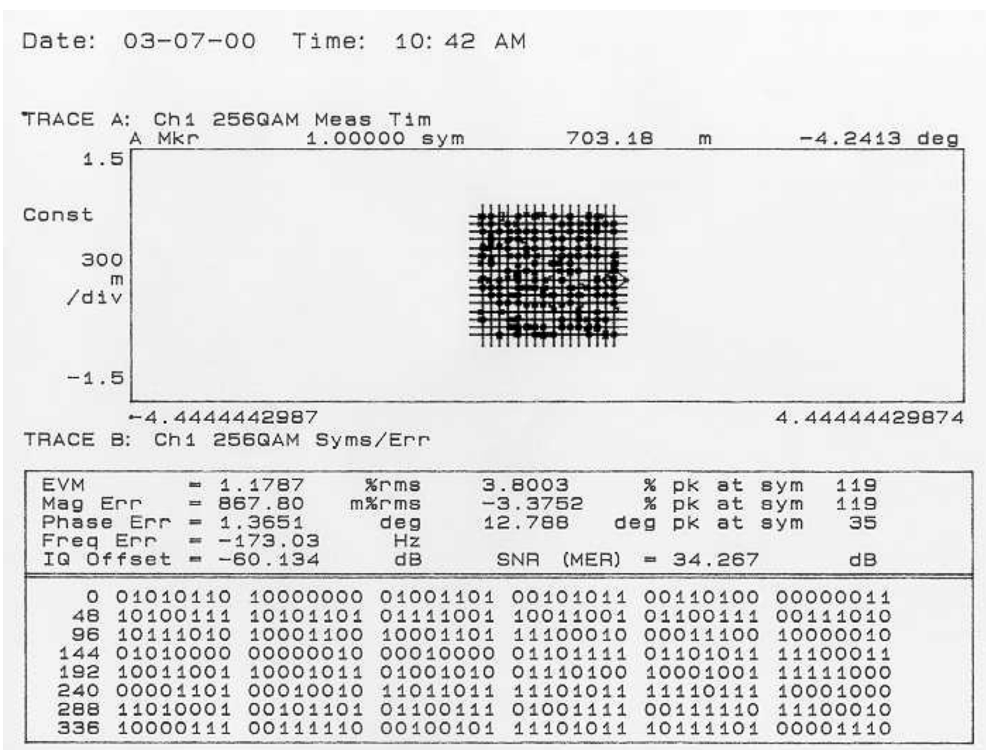


PLOT 1: Demodulation performance of the 64 QAM transmitter.



PLOT 2: Demodulation performance of the 256 QAM transmitter.

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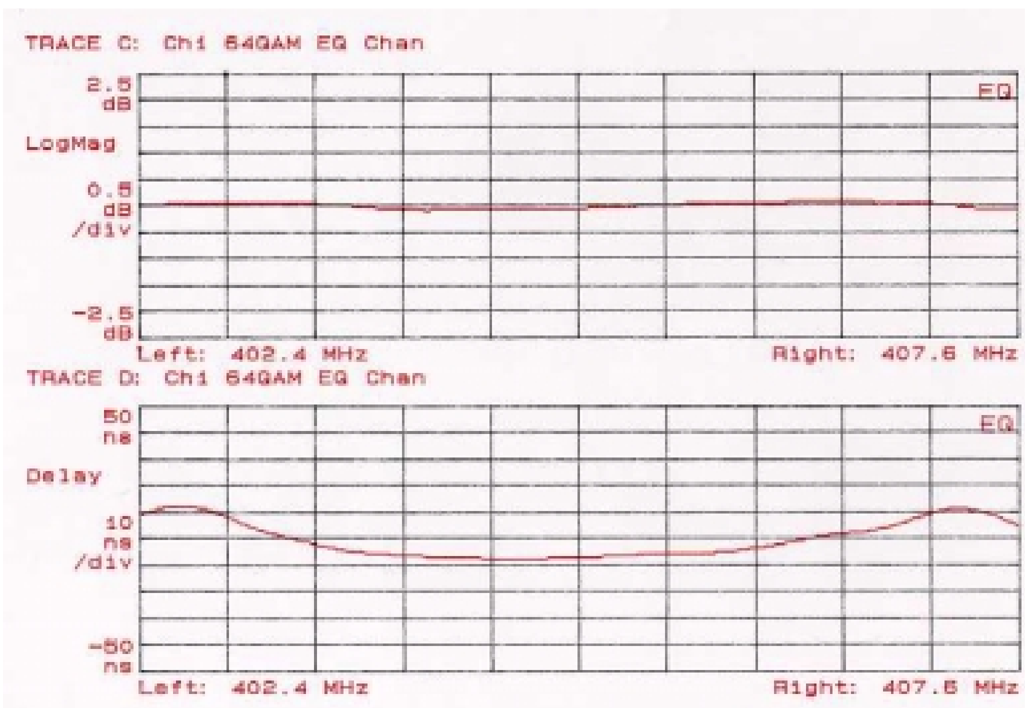
- GROUP DELAY

FCC Section 73.687 (a) (3)

Output Power:	25 watts average QAM modulation; 20 watts average QAM modulation with three equally spaced 2 MHz carriers
% Video Modulation:	Not applicable
Type Video Modulation:	Not applicable
Aural Output Power:	Not applicable
Method of Measurement:	Per EIA RS-240, Section B (12c)



PLOT 3: Frequency response and group delay of the 64 QAM transmitter.

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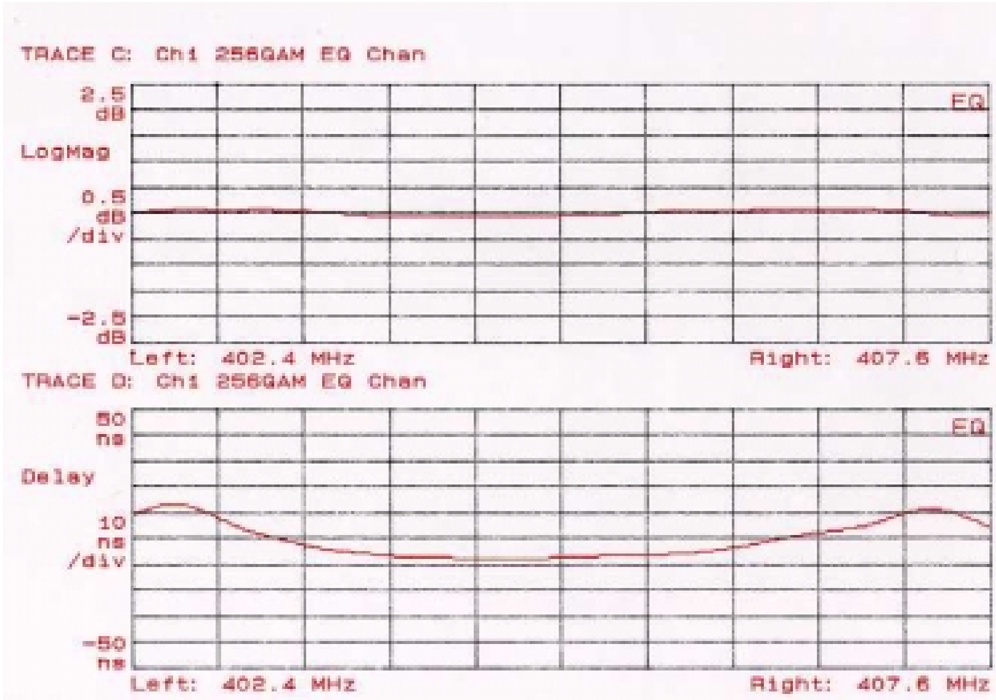


PLOT 4: Frequency response and group delay of the 256 QAM transmitter.

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

See the above plots for frequency response data.

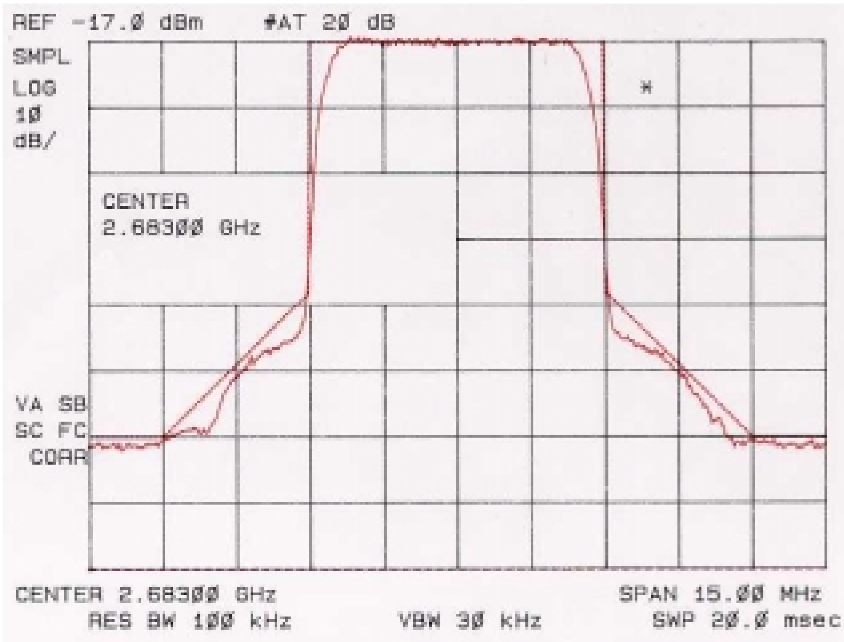
❖ <u>OCCUPIED BANDWIDTH</u>
FCC Section 2.1047/2.1049/73.687 (a) (2)/74.936

Plots five and six demonstrate 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 spectral 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.

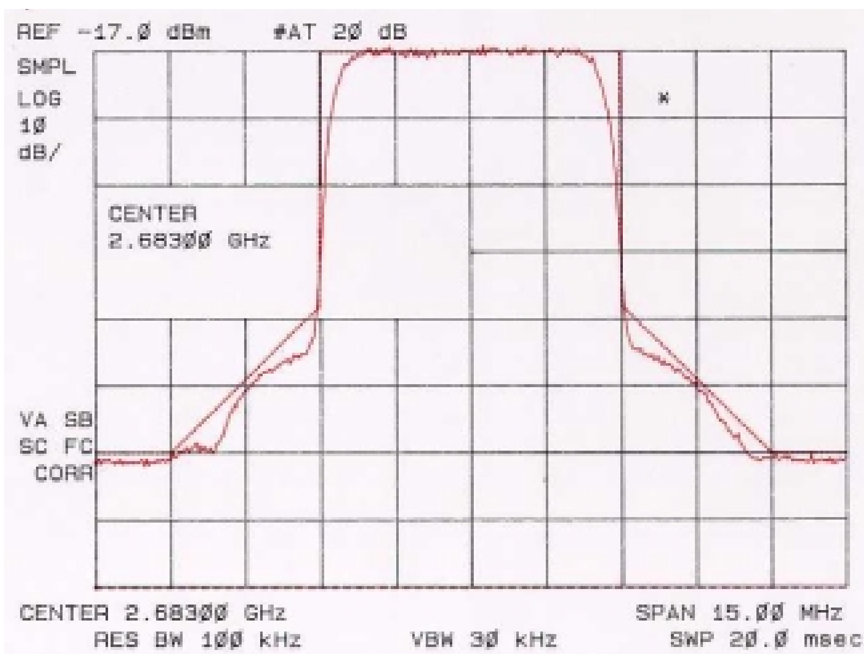
Plot seven demonstrates the occupied bandwidth of the 64 QAM modulation with three equally spaced carriers. The additional 1 dB backoff shown in plot seven follows the well known requirements for multi-carrier systems. Specifically, Leffel[1] cites results showing the backoff requirement of 1 dB when signals are increased from two to three carriers. Our laboratory test results reflect the backoff requirement predicated by Leffel. That requirement is incorporated in the rated output power of our transmitter, therefore, using the QAM modulation with three equally spaced 2 MHz carriers our transmitter is rated to 20 watts..

Each occupied bandwidth plot is labeled corresponding to the respective modulation format.

[1] Leffel, Michael, (Intermodulation Distortion in a Multi-Signal Environment), RF Design, June 1995



PLOT 5: Occupied bandwidth of the 64 QAM transmitter.



PLOT 6: Occupied bandwidth of the 256 QAM transmitter.

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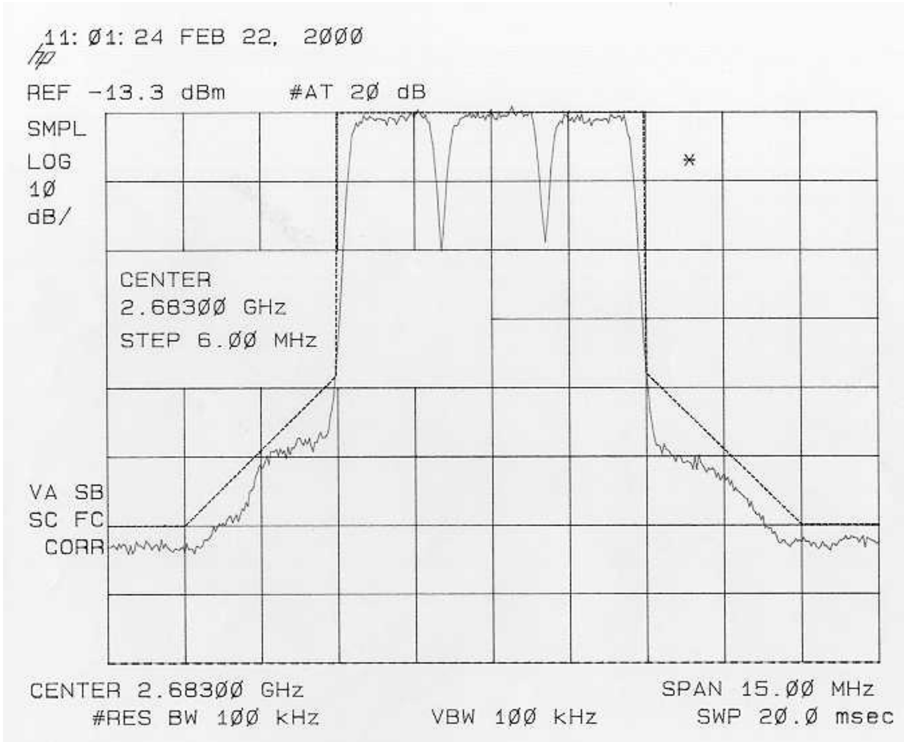

PLOT 7: Occupied bandwidth of the QAM modulation with three equally spaced 2MHz carriers[2].

❖ <u>SPURIOUS EMISSIONS AT ANTENNA TERMINALS</u>

FCC Section 2.1051/2.1057/21.908 (b)/74.936

Average Output Power:	25 watts average QAM modulation; 20 watts average QAM modulation with three equally spaced 2 MHz carriers
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
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

[2] Test was performed using a spectral shaping assembly and a channel combiner. The agile is routed to the correct filtering system by the spectral shaping assembly.

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Table 4: Spurious emissions.

Frequency (MHz)	Amplitude (dBc)	
2683.00	0	Carrier Reference
351.00	<-70	2nd IF
2332.00	-71	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

No other spurious emissions detected.

❖ FIELD STRENGTH OF SPURIOUS RADIATION

FCC Section 2.1053, 2.1057

Average Output Power: 25 watts average QAM modulation; 20 watts average QAM modulation with three equally spaced 2 MHz carriers

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 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) (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)
= 46.15 dBm

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

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

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

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

= Antilog 0.5479

E = 3.531 v/m[3]

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
351 MHz	*Below analyzer threshold	N/A	<-90
2332 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
Video Average:	ON
Attenuation:	10 dB
Span:	5 MHz

❖ FREQUENCY STABILITY

FCC Section 2.1055 (a) (1) / 74.961

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

Example 1

UHF L.O. (Synthesized)	395.00 MHz
IF Frequency (Modulator*)	- 44.00 MHz
2nd IF Frequency	351.00 MHz

[3] When using 3 carriers a 1 dB backoff occurs, therefore the received power level for 43 dBm is 3.147 v/m.

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Example 2

Microwave L.O. (Synthesized)	2332.00 MHz
2nd IF Frequency	+351.00 MHz
On Channel Frequency	2683.00 MHz

**Modulator is certified separately.*

Frequency Stability over Temperature: **Synthesizer**

Table 6: Frequency stability of Microwave LO over temperature.

Temperature	Frequency (GHz)	Error (Hz)
+25	2.332000010	10
-30	2.331999984	-16
-20	2.331999980	-20
-10	2.331999992	-8
0	2.332000000	0
+10	2.332000011	11
+20	2.332000007	7
+30	2.332000014	14
+40	2.332000012	12
+50	2.332000007	7

Error is referenced to 25º C.

Table 7: Frequency stability of UHF LO over temperature.

Temperature	Frequency (GHz)	Error (Hz)
+25	395.000006	6
-30	394.999995	-5
-20	394.999997	-3
-10	394.999998	-2
0	395.000006	6
+10	395.000007	7
+20	395.000007	7
+30	395.000008	8
+40	395.000010	10
+50	395.000012	12

Error is referenced to 25º C.

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Frequency Stability over AC Input Voltage: **Synthesizer**

Table 8: Frequency stability of Microwave LO over AC input voltage.

AC Line (V)	LO Frequency (MHz)	Error (Hz)
95	2332.000014	14.0
100	2332.000010	10.0
110	2332.000009	9.0
115	2332.000008	8.0
120	2332.000009	9.0
125	2332.000008	8.0
130	2332.000009	9.0
135	2332.000008	8.0

Error is referenced to 117 volts AC.

Table 9: Frequency stability of UHF LO over AC input voltage.

AC Line (V)	LO Frequency (MHz)	Error (Hz)
95	395.000010	10.0
100	395.000005	5.0
110	395.000005	5.0
115	395.000005	5.0
120	395.000006	6.0
125	395.000005	5.0
130	395.000005	5.0
135	395.000005	5.0

Error is referenced to 117 volts AC.

NOTE:
Frequency stability of the Microwave and UHF LO is totally dependent on the accuracy and stability of the 10 MHz reference oscillator. This is a purchased item with $\pm 2 \times 10^{-8}$ stability over temperature range.

Combining the worst case of the UHF upconverter module and the microwave synthesizer frequency shift results in a 47 Hz on channel error. This represents an accuracy which is well within the required channel ±1 KHz tolerance requirement set for ITFS/MMDS transmitters.

4.0 SUMMARY

This report demonstrates that the SDA2500C frequency agile digital television transmitter meets or exceeds the FCC certification criteria. The specified modulation format 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 synthesizer over variations in temperature and input AC line voltage showed a maximum worst case frequency shift of 47 Hz.