Final Engineering Report

KNUI – 550 kHz, 1 kW NDA
KCIK – 740 kHz, 5 kW NDA
KMVI – 900 kHz, 5 kW NDA
KUAU – 1570 kHz, 15 kW NDA

Kihei, Maui, HI

Installation and Field Tuning of Quadplexing Equipment for the Addition of KNUI to Existing Triplexing System

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Executive Summary

The AM site near Kihei, HI on the Maui island has operated as a triplexing station since 2013 when KCIK (740 kHz) was added to the existing diplexer including the original KMVI (900 kHz) and station KUAU (1570 kHz) which had been added in 2009. In this latest iteration, station KNUI (550 kHz) moves from its location near Wailuku on the north side of the island to this site to form a quadplexer, with the three existing stations employing new filter networks to reject 550 kHz, and KNUI (550 kHz) employing all new matching and filtering networks, with all new networks being manufactured by Kintronic Labs, Inc. (KTL).

Two site visits were made by the KTL Senior Field Engineer for the purpose of tuning and commissioning the updated system, along with the gathering of the various measurements and data required to be submitted in conjunction with the FCC Form 302-AM for each of the four stations to obtain updated licenses. These visits took place April 22 – May 5, 2023, and 22-30 July 2023. The present report documents various aspects of the installation process, and provides the requisite measurement data for inclusion with the 302 – AM filing.

Measurements

All impedance and filter characteristics measurements were made with an HP 8751A Network Analyzer in conjunction with a Tunwall Radio directional coupler and an ENI 300L RF amplifier in a calibrated measurement set up, and are presented below. Signal strength measurements were made with a Potomac Instruments Field Strength Meter model FIM-41, and where indicated below, with an Anritsu Spectrum Analyzer model MS2712E, in conjunction with a Chris Scott and Assoc. AM loop antenna model LP-3.

General Outline of material:

1. Tower Impedance Measurements
2. Filter Characteristics
3. KNUI (550 kHz) Characterization After Tuning
4. KCIK (740 kHz) Characterization After Tuning
5. KMVI (900 kHz) Characterization After Tuning
6. KUAU (1570 kHz) Characterization After Tuning
7. Spurious emissions assessment at Intermodulation Frequencies
8. Updated RF Schematic (for reference)

Tower Impedance Measurements

Measurements of the "bare" tower impedance were made for each of the four carrier frequencies, at the respective "final output" J-plug for each station:

- For 550 kHz (KNUI): J106
- For 740 kHz (KCIK): J202
- For 900 kHz (KMVI): J302
- For 1570 kHz (KUAU): J201

The "bare" tower impedance is the impedance measured with all of the "final output" J-plugs open, so the stray capacitance contributed from the filter networks are not included in the measurement. The tower base effects contributed by the cabinets themselves being in close proximity to the tower are, of course, included in these measurements.

A second set of measurements was made which did include all of the stray capacitance of the networks, and also which included the contribution of the "overall washout coil" system at the output of the 550 kHz system. For these measurements, the same measurement point as was used before was used for each station, with the exception of 550 kHz, for which station the J105 J-plug was used, with J106 closed. This measurement is presented as the "Actual" Tower Load. It also should be noted that the measurement presented here is after the final configuration of the "overall washout" coil system was in place, and set to the nominal (total combined) value of 25 μH. Measurements were made only at the carrier frequencies, and are presented below:

Station	Freq. (kHz)	"Bare" Tower Z (Ω)	"Actual" Tower Load Z (Ω)
KNUI	550	10.6 – j139	108 + j362
KCIK	740	23.3 – j28.3	37.1 – j33.8
KMVI	900	57.5 + j80.4	43.6 + j78.4
KUAU	1570	105 – j283	20.9 – j98.6

Filter Characteristics

There are 12 series filters in the overall quadplexing system, to protect each station from signals originating from the other three stations. The 1570 kHz system also has an additional shunt filter at its input point for further protection from the 550 kHz system.

Measurements were made during the April/May trip to assess the isolation characteristics of the 12 series filters. The additional shunt filter for the 1570 kHz system was added during the July trip. Since this filter had been recently tuned at the factory, its characteristics were not measured on site. For the other filters, adjustments were made only where needed.

The 1570 kHz reject filter in the 900 kHz system needed to be rebuilt on site due to significant arcing that occurred when the 1570 kHz system was operating; the filter characteristics presented below represent the condition after this filter was redesigned, rebuilt, and retuned.

The final measurement results of the isolation provided by each filter are presented below:

550 kHz system:

740 kHz reject filter:
550 kHz: 0.6 – j0.5
740 kHz: 11.0k + j10.1k

900 kHz reject filter:
550 kHz: 0.3 – j0.6
900 kHz: 6.9k – j22.2k

1570 kHz reject filter:
550 kHz: 0.6 – j0.3
1570 kHz: -1k – j5.8k

740 kHz system:

550 kHz reject filter:
740 kHz: 0.3 – j5.2
550 kHz: 26.5k – j15.8k

900 kHz reject filter:
740 kHz: 0.4 + j1.0
900 kHz: 141 – j1.4k

1570 kHz reject filter:
740 kHz: 0.2 – j0.3
1570 kHz: -160 – j1.6k

900 kHz system:

550 kHz reject filter:
900 kHz: 0.6 – j6.0
550 kHz: 2.5k – j13k

740 kHz reject filter:
900 kHz: 0.1 – j13.6
740 kHz: 5.7k + j8.2k

1570 kHz reject filter (as rebuilt):
900 kHz: 0.5 + j0.5
1570 kHz: 5k + j11k

1570 kHz system:

550 kHz reject filter:
1570 kHz: -0.3 – j17.6
550 kHz: 1.0k – j11.6k

740 kHz reject filter:
1570 kHz: -0.5 – j17.8
740 kHz: 210 – j4.7k

900 kHz reject filter:
1570 kHz: 0.2 – j0.6
900 kHz: 495 – j5.0k

KNUI Station (550 kHz) Characterization After Tuning

After all adjustments were made as needed to the filtering and matching networks, measurements of the input match impedance and SWR were made at the input J-plug J101. Impedance on the carrier frequency was also measured at the load side of the matching network, where the base current is monitored (at J-plug J102). The measurement at J102 (on carrier) is the value to be reported on the 302-AM form as the (effective) tower base impedance, corresponding to the current measurement point for calculating outgoing power, and is designated in the data table below as "Output Z." The current corresponding to full broadcast power (as well as the +5% and -10% tolerance values) have been calculated and are reported below.

Freq. (kHz)	Input Z	SWR	"Output" Z
535	2.6 – j21.4	22.5	
540	4.9 – j14.7	11.2	
545	12.7 – j3.7	3.951	
550	**50.3 – j0.5**	**1.013**	**29.9 + j213**
555	35.6 – j57.2	3.679	
560	10.5 – j46.8	9.0	
565	4.9 – j37.8	16.2	

Calculated Current Values:

The direct measurement of power is based on the current where monitored in the system, and the impedance measured at that point, in this case, at J-plug J102. The current values corresponding to nominal full power, and the + 5% and -10% tolerance values are calculated and presented below:

	Power (W)	Current (A)
Full Power – 10%:	900	5.49
Nominal:	1000	5.78
Full Power + 5%:	1050	5.93

The values to be reported on the Form 302-AM are: Resistance: 29.9 Ω, and nominal current of 5.8 A (both day and night).

KCIK Station (740 kHz) Characterization After Tuning

After all adjustments were made as needed to the filtering and matching networks, measurements of the input match impedance and SWR were made at the input J-plug J201. Impedance on the carrier frequency was also measured at the load side of the matching network, where the base current is monitored (at J-plug J202). The measurement at J202 (on carrier) is the value to be reported on the 302-AM form as the (effective) tower base impedance, corresponding to the current measurement point for calculating outgoing power, and is designated in the data table below as "Output Z." The current corresponding to full broadcast power (as well as the +5% and -10% tolerance values) have been calculated and are reported below.

Freq. (kHz)	Input Z	SWR	"Output" Z
725	18.6 + j6.5	2.745	
730	26.9 + j10.8	1.980	
735	38.8 + j10.2	1.407	
740	**50.2 – j0.1**	**1.004**	**39.5 – j38.4**
745	50.4 – j17.2	1.407	
750	39.5 – j27.8	1.929	
755	27.8 – j29.4	2.591	

Calculated Current Values:

The direct measurement of power is based on the current where monitored in the system, and the impedance measured at that point, in this case, at J-plug J202. The current values corresponding to nominal full power, and the + 5% and -10% tolerance values are calculated and presented below:

	Power (W)	Current (A)
Full Power – 10%:	4500	10.67
Nominal:	5000	11.25
Full Power + 5%:	5250	11.53

The values to be reported on the Form 302-AM are: Resistance: 39.5 Ω, and nominal current of 11.3 A (both day and night).

KMVI Station (900 kHz) Characterization After Tuning

After all adjustments were made as needed to the filtering and matching networks, measurements of the input match impedance and SWR were made at the input J-plug J1. Impedance on the carrier frequency was also measured at the load side of the matching network, where the base current is monitored (at J-plug J2). The measurement at J2 (on carrier) is the value to be reported on the 302-AM form as the (effective) tower base impedance, corresponding to the current measurement point for calculating outgoing power, and is designated in the data table below as "Output Z." The current corresponding to full broadcast power (as well as the +5% and -10% tolerance values) have been calculated and are reported below.

Freq. (kHz)	Input Z	SWR	"Output" Z
885	136 – j15.5	2.761	
890	93.6 – j23.7	2.035	
895	65.8 – j14.0	1.442	
900	**49.9 + j0.2**	**1.006**	**75.4 + j121**
905	41.4 + j15.7	1.480	
910	39.2 + j33.6	2.173	
915	50.6 + j59.7	3.082	

Calculated Current Values:

The direct measurement of power is based on the current where monitored in the system, and the impedance measured at that point, in this case, at J-plug J2. The current values corresponding to nominal full power, and the + 5% and -10% tolerance values are calculated and presented below:

	Power (W)	Current (A)
Full Power – 10%:	4500	7.73
Nominal:	5000	8.14
Full Power + 5%:	5250	8.34

The values to be reported on the Form 302-AM are: Resistance: 75.4 Ω, and nominal current of 8.1 A (both day and night).

KUAU Station (1570 kHz) Characterization After Tuning

After all adjustments were made as needed to the filtering and matching networks, measurements of the input match impedance and SWR were made at the input J-plug J101. The impedance at the load side of the matching networks was measured (on carrier) for reference only, and is designated as "Output Z" in the table below. In this network, the current monitoring toroid is located at the input J-plug (J101), and so the impedance to be reported on the 302-AM form is the input impedance, and the outgoing power is calculated at this point in the system. The current corresponding to full broadcast power (as well as the +5% and -10% tolerance values) have been calculated and are reported below.

Freq. (kHz)	Input Z	SWR	"Output" Z (reference only)
1555	31.9 – j34.0	2.534	
1560	36.2 – j24.3	1.905	
1565	42.1 – j13.1	1.393	
1570	**50.04 – j0.1**	**1.004**	**91.5 – j70.8**
1575	61.7 + j15.3	1.411	
1580	79.1 + j15.3	2.001	
1585	107 + j55.2	2.821	

Calculated Current Values:

The direct measurement of power is based on the current where monitored in the system, and the impedance measured at that point, in this case, at the input J-plug (J101). The current values corresponding to nominal full power, and the + 5% and -10% tolerance values are calculated and presented below:

	Power (W)	Current (A)
Full Power – 10%:	13,500	16.43
Nominal:	15,000	17.32
Full Power + 5%:	15,750	17.75

The values to be reported on the Form 302-AM are: Resistance: 50.0 Ω, and nominal current of 17.3 A (both day and night).

Field Strength Measurements at Intermodulation Product Frequencies

Field strength measurements of the unmodulated signal at full licensed power were made at the carrier frequencies of each station to be used as reference values. Intermodulation frequencies were calculated (up to 4th Order) determined by linear combinations of the four carrier frequencies, falling between 500 kHz and 5.0 MHz. These are subdivided into those frequencies falling within the AM band (43 separate frequencies), and those above the AM band up to 5 MHz (81 frequencies), for a total of 124 frequencies at which spurious transmissions are theoretically possible to be emitted.

Making individual measurements at each and every one of these frequencies was deemed unduly unwieldy, and a more efficient and systematic approach seemed appropriate.

Each station was operating at the power level its transmitter was capable of without issue, up to the full authorized power level, with normal audio modulation. The 550 kHz and 740 kHz stations operated at their full authorized powers of 1.0 kW and 5.0 kW, respectively. The 900 kHz station operated at 3.8 kW, the highest power the transmitter was capable of producing. The 1570 kHz station operated at 5.0 kW, due to arcing conditions taking place at the STL isocoupler (not at all related to the antenna system operations) taking place at higher output power levels. All measurements made used the reference levels based on the actual transmitter output levels in effect at the time. While this approach could be considered not to follow the strict interpretation of FCC rules relative to these measurements, it should be understood that the approach used was consistent with the "spirit" of these regulations, and were the best approach available at the time under the existing test conditions.

Since the power level of at least one of the stations being measured was 1.0 kW, a measurement location was chosen closer to the transmitter site than the 1.0 km distance referenced in the FCC language. It is well known that for stations operating at relatively low power, measurement locations far closer than 1 km are often required to obtain favorable signal-to-noise ratios needed for meaningful measurements. The selected measurement location for these measurements was at a "driveway" on the opposite side of Highway 311 near the transmitter site. This site was at a distance of 0.16 km, and at a bearing of 223° from the transmitting tower. There were no overhead wires or possible reradiating objects observed in the immediate vicinity of the measurement location.

Measurements at the second harmonic frequencies relative to the two lower carrier frequencies were made using the FIM-41 meter.

All other measurements were made using the Spectrum Analyzer in conjunction with the Chris Scott AM loop antenna. For measurements within the AM band, sweeps were made in 200 kHz spans from 500 kHz to 2000 kHz. For the frequency range of 2000 – 5000 kHz, sweeps were made in 500 kHz spans. Most of the calculated intermodulation frequencies (for the entire spectrum) indicated no spurious emissions (signal levels were completely in the noise floor). At frequencies for which there was some signal that rose above the noise floor, a measurement was made and subsequently analyzed. The resulting measurements and analysis are presented in the table appearing below. It should be noted here that at calculated intermodulation frequencies

which are not presented in this table, the signal strength was at those frequencies indistinguishable from the noise floor, and therefore not considered. With the exception of signals clearly attributable to other radio stations, there were no spurious emissions detected at any of the 124 calculated intermodulation product frequencies, and it is safely concluded that the filters in the overall quadplexing system are sufficient to prevent such spurious emissions.

The several frequencies which were given closer examination for this analysis, and their assessment, are presented in the table below.

Field Strength Measurements at Intermodulation Product Frequencies and Calculated Strengths Relative to Carriers in dB

Stations:

	Call letters:	Freq.	Power (W)	Unmod. Carrier reading (mV/m)
A	KNUI	550	1000	1950
B	KCIK	740	5000	4900
C	KMVI	900	3800	3500
D	KUAU	1570	5000	4700

Date and Time of measurements: 30 July 2023, between 1500 – 1700 hrs

	IM Frequency	A F1	A F2	A F3	A F4	Origin	Spec.An.	equiv. calc. reading	Reading (mV/m)	Note	relative to 550 (dB)	limit	relative to 740 (dB)	limit	relative to 900 (dB)	limit	relative to 1570 (dB)	limit
	1100	550	360	200	470	2A			0.0150		-102.3	-73.0	-110.3	-80.0	-107.4	-78.8	-109.9	-80.0
	1480	930	740	580	90	2B			0.0480		-92.2	-73.0	-100.2	-80.0	-97.3	-78.8	-99.8	-80.0
	580	30	160	320	990	2B-C	78.3	0.237	0.2370	4	-78.3	-35.0	-86.3	-80.0	-83.4	-78.8	-85.9	-80.0
	620	70	120	280	950	A+B+C-D	90	0.062	0.0620	4	-90.0	-65.0	-98.0	-80.0	-95.0	-78.8	-97.6	-80.0
	640	90	100	260	930	A-2B+D	89.3	0.067	0.0670		-89.3	-73.0	-97.3	-80.0	-94.4	-78.8	-96.9	-80.0
KPUA	670	120	70	230	900	D-C	64.5	1.162	1.1620	2,4	-64.5	-73.0	-72.5	-65.0	-69.6	-78.8	-72.1	-80.0
KHVH	830	280	90	70	740	D-B	72.3	0.473	0.4730	3,4	-72.3	-73.0	-80.3	-80.0	-77.4	-65.0	-79.9	-80.0
	860	310	120	40	710	B+D-A-C	75.96	0.31	0.3100	4	-76.0	-73.0	-84.0	-80.0	-81.1	-45.0	-83.6	-80.0
	930	380	190	30	640	2B-A	72.5	0.462	0.4620	4	-72.5	-73.0	-80.5	-80.0	-77.6	-35.0	-80.1	-80.0
KKI	990	440	250	90	580	C+D-2B	82.1	0.153	0.1530		-82.1	-73.0	-90.1	-80.0	-87.2	-95.0	-89.7	-80.0
	1670	1120	930	770	100	3B-A	76.1	0.306	0.3060		-76.1	-73.0	-84.1	-80.0	-81.2	-77.5.0	-83.7	-80.0
	2310	1760	1570	1410	740	B+D	72.9	0.442	0.4420		-72.9	-73.0	-80.9	-80.0	-78.0	-78.8	-80.5	-80.0
	2470	1920	1730	1570	900	C+D	75.3	0.185	0.1850		-75.3	-73.0	-83.3	-80.0	-80.4	-78.8	-82.9	-80.0
	3140	2590	2400	2240	1570	2D	75.1	0.343	0.3430		-75.1	-73.0	-83.1	-80.0	-80.2	-78.8	-82.7	-80.0

NOTES:

1 Isolation limits are calculated using formulae cited in FCC Rules 73.44

2 Signal was from KPUA station

3 Signal was from KHVH station

4 Limits are reduced per FCC Rules 73.44 for frequencies separated from carrier by 75 kHz or less, on graduated scale.

RF Schematic