

# A Prototype Analog Receiver for LWA

Mahmud Harun\* and S.W. Ellingson

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\*Bradley Dept. of Electrical & Computer Engineering, Virginia Polytechnic Institute & State University, Blacksburg VA 24061 USA. E-mail: [mharun@vt.edu](mailto:mharun@vt.edu)

# 1 Introduction

An analog receiver exists for the Eight-meter wavelength Transient Array (ETA) telescope operating in the band 29-47 MHz [1, 2]. This design has been modified to work as a preliminary prototype for the Long Wavelength Array (LWA) by replacing the filter sections with the new filter sections described in [3]. This receiver is intended to be located between the long cable from the antenna and digitizer, as discussed in [4]. The gain, noise figure, and IIP<sub>3</sub> of this new design are about 54 dB, 6 dB, and -16 dBm respectively. In this document we (1) provide the detailed design of the receiver, (2) quantify the predicted performance, and (3) show the results of the measurements on the new receiver.

# 2 Design

The design of the receiver is shown in Figures 1 and 2.

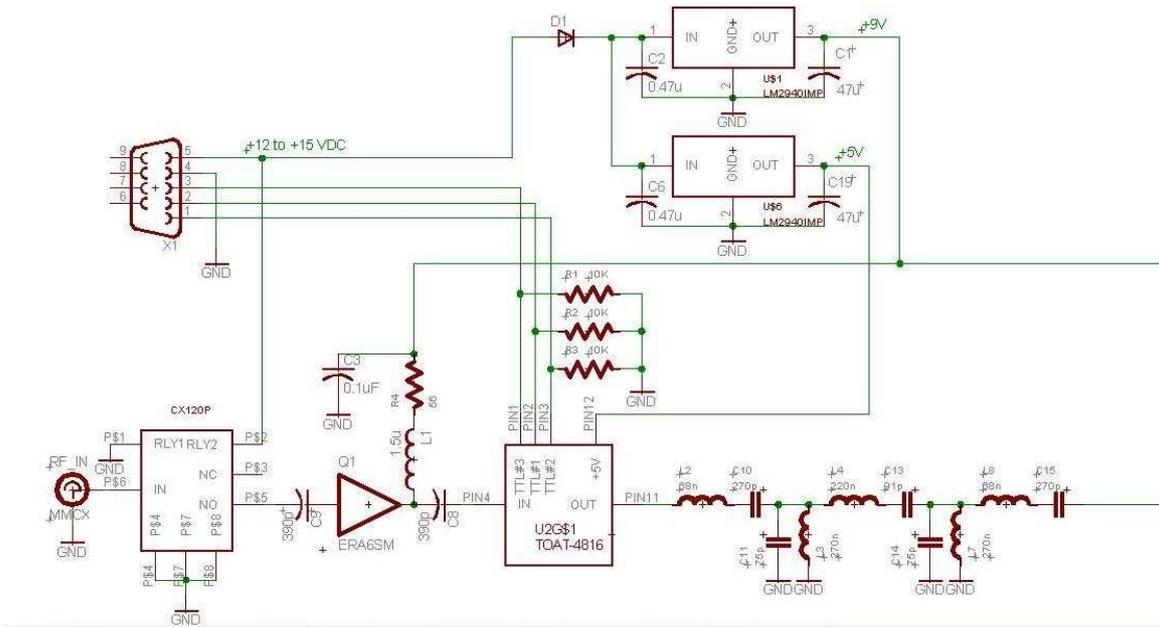


Figure 1: Receiver schematic (part 1 of 2).

A detailed component list for this design is provided in Appendix A. Additional details pertaining to the filter design are given in [3].

A picture of assembled receiver is shown in Figure 3. A summary of the cost of this receiver board is presented in the Appendix.

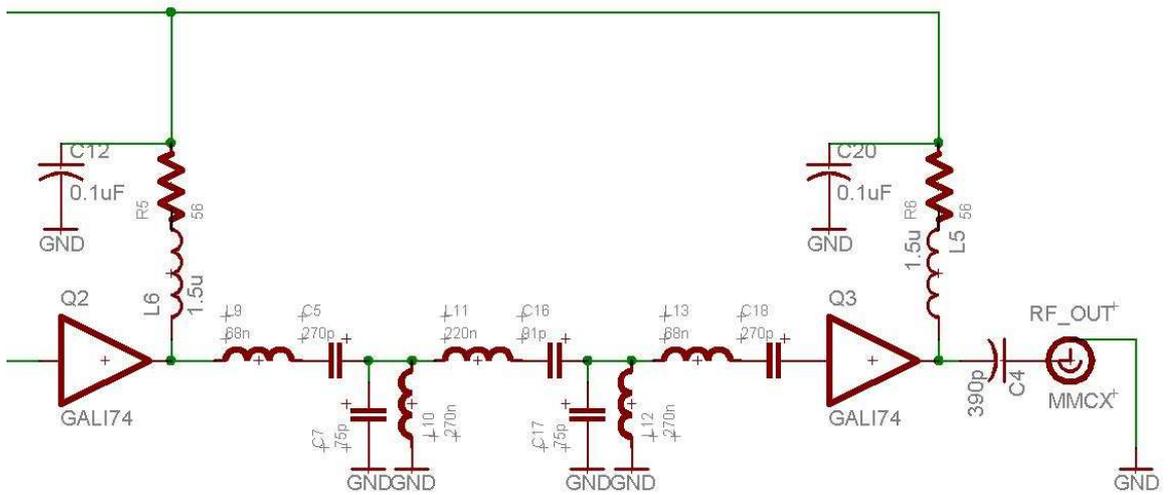


Figure 2: Receiver schematic (part 2 of 2).

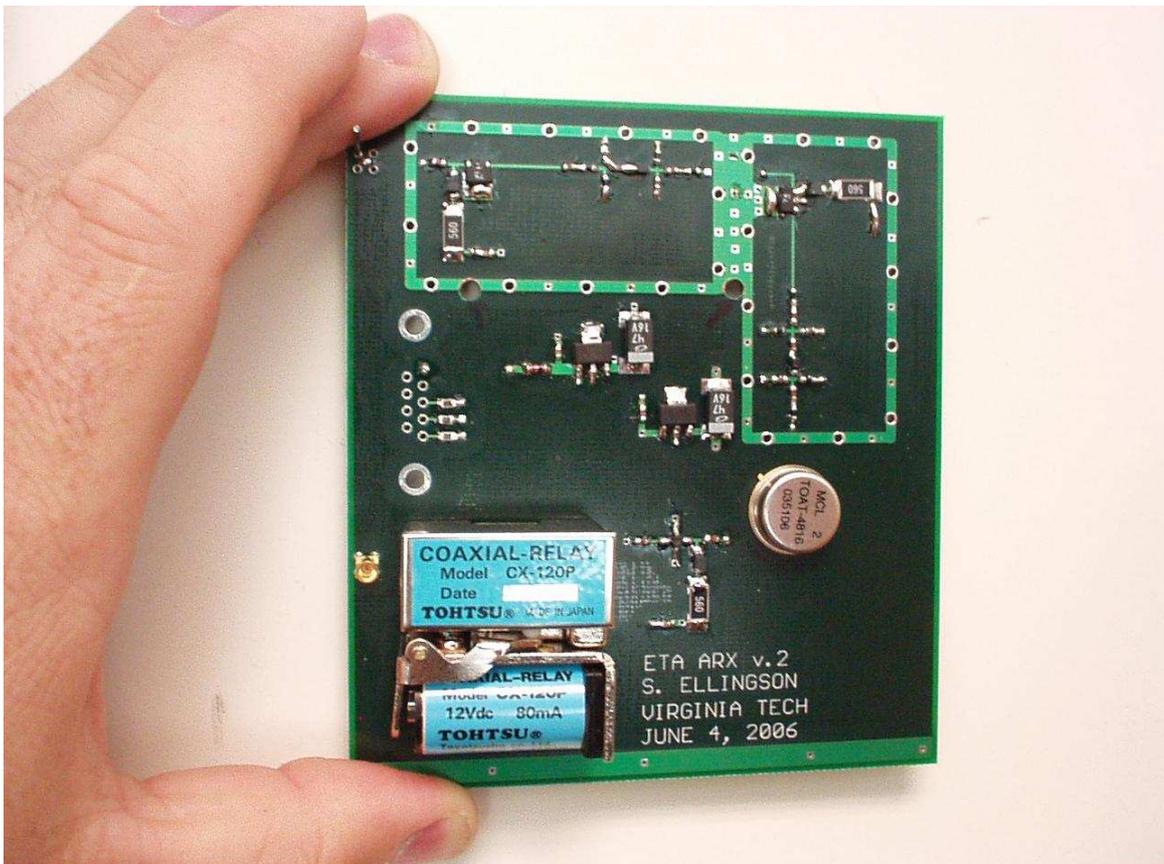


Figure 3: Assembled receiver (Note this is actually a picture of the ETA receiver, but the receiver described in this document is identical since the only change is values of the SMT components in the bandpass filters).

### 3 Predicted Performance

In this section the performance of the design given in Section 2 is predicted. An analysis of gain (G), noise figure (F), and output third-order intercept point ( $OIP_3$ ) is shown in the following table.

Stage	Component	Stage			Cascade		
		Gain[dB]	F[dB]	$OIP_3$ [dBm]	Gain[dB]	F[dB]	$OIP_3$ [dBm]
1	Coaxial Relay	-1.0	1.0	200.0	-1.0	1.0	200.0
2	ERA-6	12.0	4.5	36.5	11.0	5.5	36.5
3	Digital Step Attenuator	-4.0	4.0	30.0	7.0	5.6	28.0
4	BPF	-1.4	1.4	200.0	5.6	5.7	26.7
5	GALI-74	25.1	2.7	38.0	30.7	6.0	37.8
6	BPF	-1.4	1.4	200.0	29.3	6.0	36.4
7	GALI-74	25.1	2.7	38.0	54.4	6.0	38.0

Above, we assume the digital step attenuator is set at its minimum value of 4 dB. Completing the GNI analysis we obtain the predicted receiver performance specifications of:  $G = 54$  dB,  $F = 6$  dB, and  $OIP_3 = +38$  dBm. The associated input  $IP_3$  is  $-16$  dBm. Assuming the input 1 dB compression ( $IP_{1dB}$ ) is 10-15 dB lower (typical for such designs), then we have  $IP_{1dB}$  between  $-31$  dBm and  $-26$  dBm. This is the linearity metric tested in subsequent sections.

In the version tested here we didn't install the digital step attenuator. Thus the predicted gain and  $IP_3$  for the test unit is expected to be approximately 4 dB different from what a "production unit" would provide; i.e.,  $G = 58$  dB and  $IP_{1dB}$  between  $-35$  dBm and  $-30$  dBm.

### 4 Test Results

This section deals with the results of the measurements of the receiver. The frequency response of the receiver is shown in Figure 4. This response was obtained for an input power of  $-66$  dBm, thus the measured gain is about 59 dB, i.e., about 1 dB greater than predicted. The comparison between the predicted frequency response and the measured response is shown in Figure 5. Note the good agreement with prediction and relatively flat passband in the LWA bandwidth. There is a fairly sharp cut-off at the low end but the high end does not roll off as quickly.<sup>1</sup>

<sup>1</sup>However we have very recently developed a simple revision (2 additional components) to the bandpass filters which greatly improve the suppression in the broadcast FM band by introducing a notch at 90 MHz.

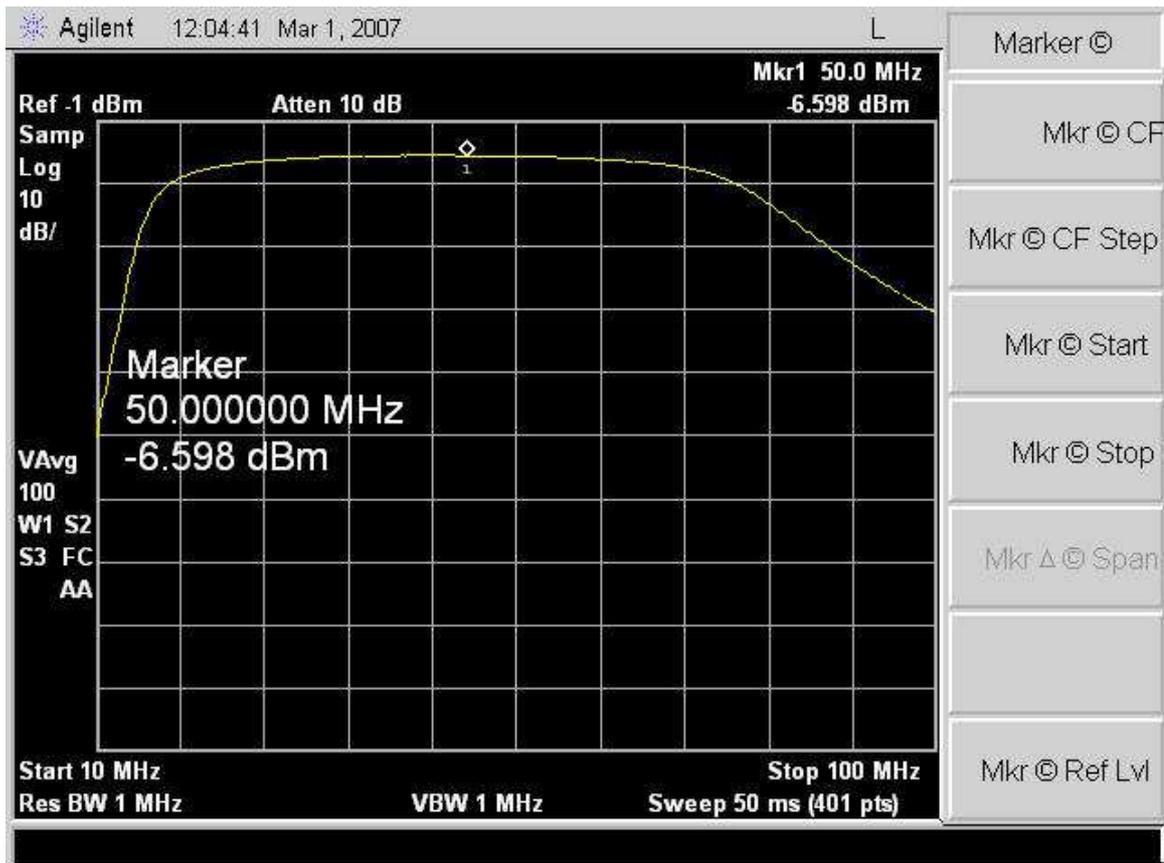


Figure 4: Frequency Response for an input power of  $-66$  dBm .

Figure 6 shows the measured input 1 dB compression point ( $IP_{1dB}$ ) of the receiver at 20, 38, 74, and 80 MHz. Note the excellent agreement with the predicted value of between  $-35$  dBm and  $-30$  dBm. Detail of the measurement at 50 MHz is presented in Figure 7.

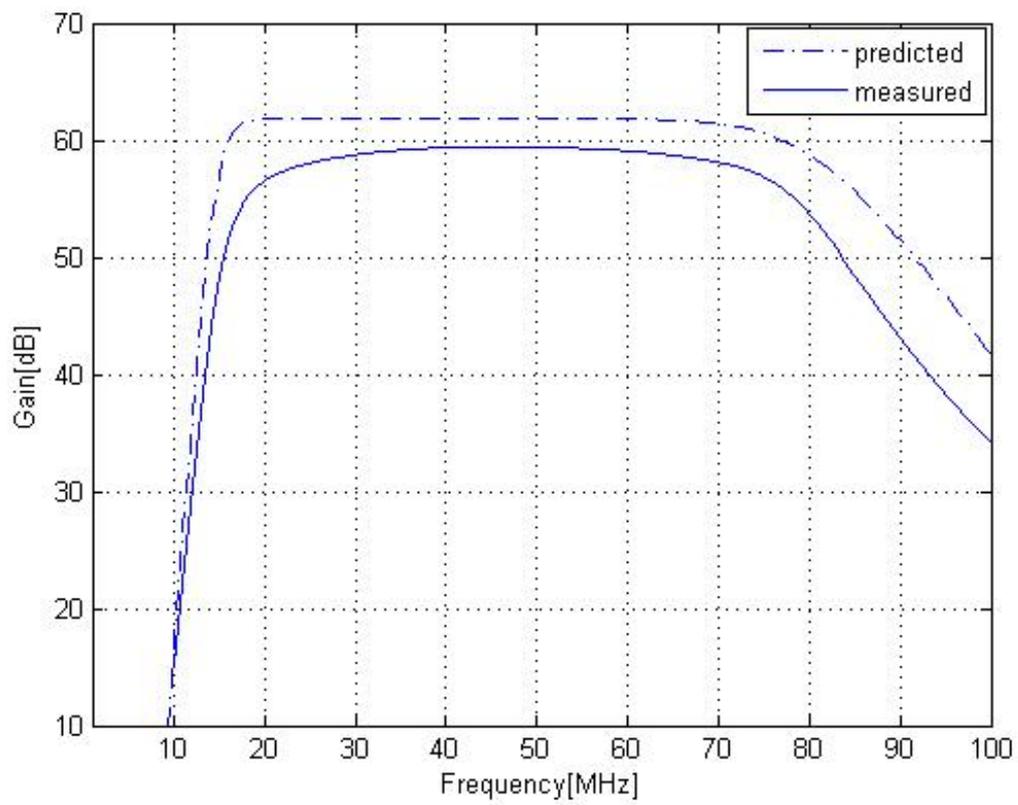


Figure 5: Comparison of predicted result (offset by +4 dB) with the measured response.

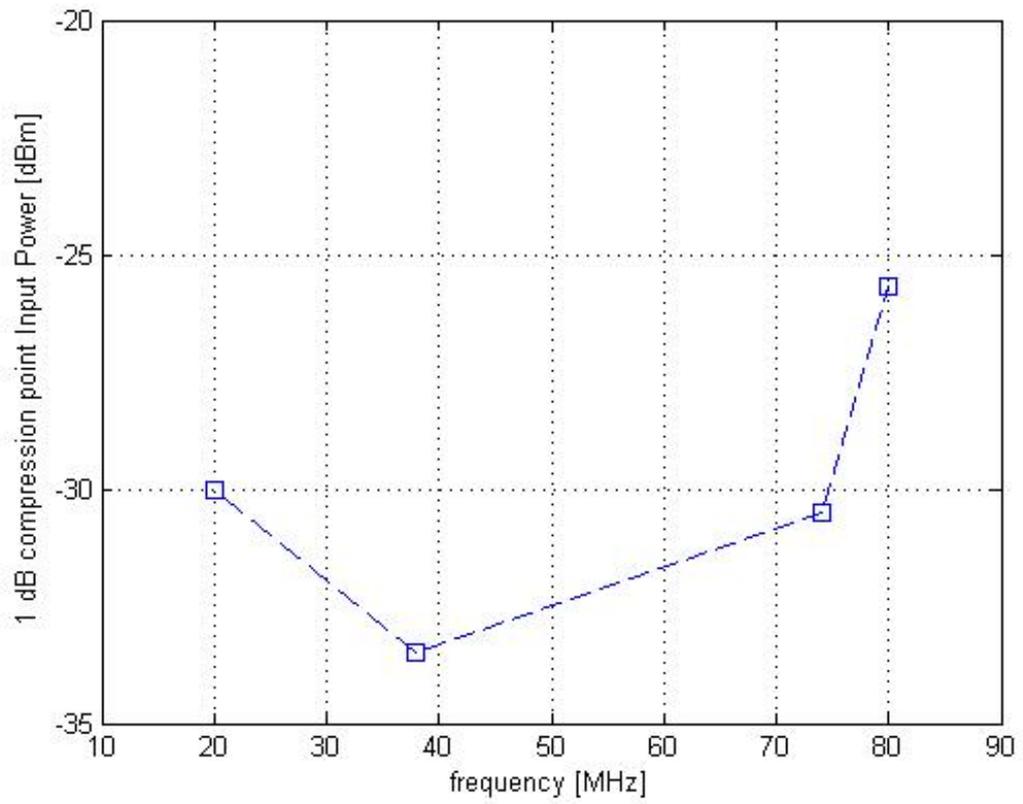


Figure 6: Input 1 dB compression point vs. frequency.

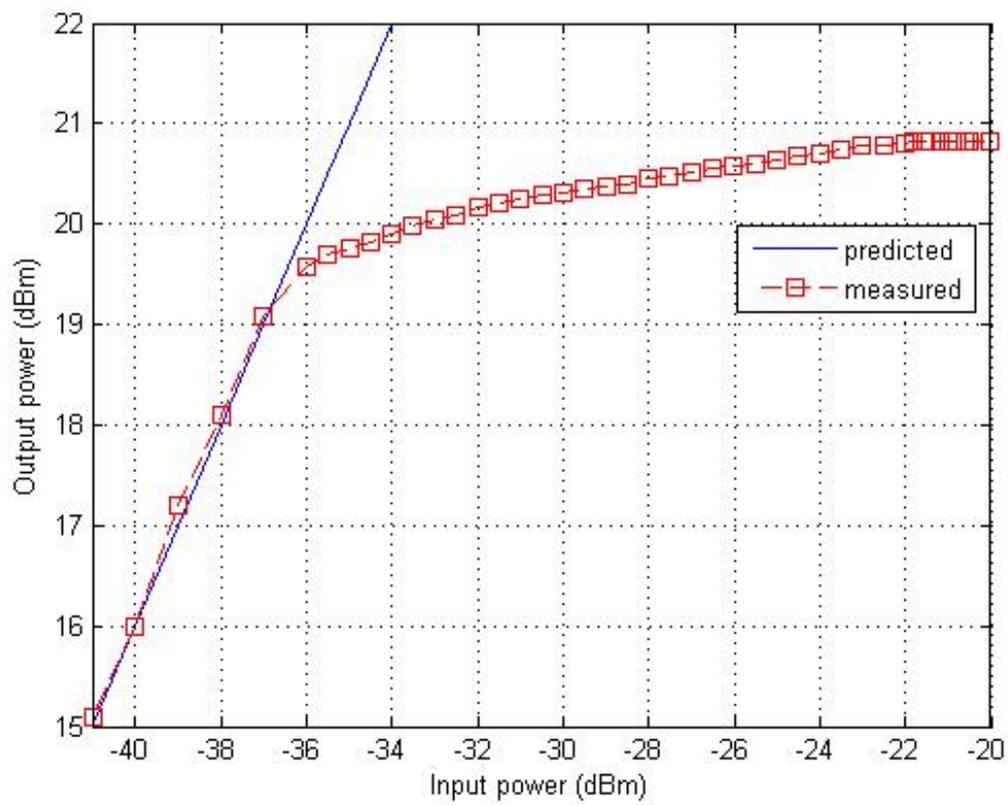


Figure 7: Measurement of input 1 dB compression point at 50 MHz.

## A Appendix: Components and Cost Data

Detailed Component List:

Description	Value	Package	Manufacturer	Manufacturer Part Number	Distributor	Distributor Part Number	Part IDs
CAP CER 50V 5% C0G	75 pF	0603 (1608)	Murata Electronics North Amer- ica	GRM1885C1 H910JA01D	Digikey	490-1426-1- ND	C11,C14,C7,C17
CAP CER 50V 5% C0G	91 pF	0603 (1608)	Murata Electronics North Amer- ica	GRM1885C1 H910JA01D	Digikey	490-1426-1- ND	C13,C16
CAP CE- RAMIC 50V NP0	270 pF	0603 (1608)	Yageo Cor- poration	CC0603JR NP09BN271	Digikey	311-1074-1- ND	C10,C15,C5,C18
CAP CER 25V	0.1 uF	0603 (1608)	Yageo Cor- poration	CC0603ZRY 5V8BB104	Digikey	311-1087-1- ND	C3,C12,C20
CAP CER 10V	0.47 uF	0603 (1608)	Kemet	C0603C474 K8PACTU	Digikey	399-3114-1- ND	C2
RES SMD 1W	56 OHM	2512	Vishay/Dale	CRCW251256 R0JNEG	Digikey	541-56XCT- ND	R4,R5,R6
INDUCTOR 340MA	68 nH	0603 (1608)	Murata Electrnoics North Amer- ica	LQW18AN 68NJ00D	Digikey	490-1178-1- ND	L2,L8,L9,L13
INDUCTOR .11A 5%	220 nH	0603 (1608)	EPCOS Inc	B82496 C3221J	Digikey	495-1834-1- ND	L4,L11
INDUCTOR 110MA	270 nH	0603 (1608)	Murata Electronics North Amer- ica	LQW18AN R27J00D	Digikey	490-1181-1- ND	L3,L7,L10,L12
Amplifier, Monolithic	-	-	Mini-Circuits	ERA-6	Mini-Circuits	ERA-6	Q1
Amplifier, Monolithic	-	-	Mini-Circuits	GALI-74	Mini-Circuits	GALI-74	Q2,Q3

Summary of cost for one LWA receiver board:

Component	Quantity	Price (US Dollar)
Capacitor	19	1.31
Inductor	13	1.74
Resistor	3	1.01
Amplifier	3	13.55
MMCX Connector	2	6.63
Coaxial Relay	1	28.00
Attenuator	1	47.00
PCB	1	162.00
Total	1	261.24

## References

- [1] “ETA Analog Receiver,” <http://www.ece.vt.edu/swe/eta/ARX/>.
- [2] Steve Ellingson, “In Situ Evaluation of the ETA Analog Signal Path,” Long Wavelength Array Memo 46, August 11, 2006, <http://www.phys.unm.edu/lwa/memos>.
- [3] M. Harun and S.W. Ellingson, “Practical Considerations in the Design of a Bandpass Filter for the LWA Analog Receiver,” Long Wavelength Array Memo 63, November 14, 2006, <http://www.phys.unm.edu/lwa/memos>.
- [4] P.S. Ray *et al.*, “A Strawman Design for the Long Wavelength Array Stations,” Long Wavelength Array Memo 35, April 11, 2006, <http://www.phys.unm.edu/lwa/memos>.