ANALOG SIGNAL PATH OF LOFASM

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Glossary

- ADC: Analog to Digital Converter
- ARX Board: Analog Receiving Board
- BCCAI: Bare Copper Clad Aluminum
- FEE: Front End Electronics
- LoFASM: Low Frequency All Sky Monitor
- LWA: Long Wavelength Array, located in New Mexico
- PE: Polyethylene
- PTFE:Polytetrafluoroethylene
- PVC: Polyvinyl Chloride
- ROACH: Reprogrammable Open Architecture Computing Hardware, which is the spectrometer for LoFASM
- VNA: Vector Network Analyzer

1 Overview

1.1 LoFASM I

The LoFASM Radio Antenna Array consists of 12 LWA style crossed dipole antennas set in two concentric rings of six antennas each. The two rings are set up in a hexagram configuration, with the inner ring being 4.41 meters from the center of the configuration, such as to monitor between 5-88 MHz with a maximum sensitivity at 20 MHz. At the top of the antenna is the Front End Electronics(FEE) Board, which is bolted to the dipoles. Connected to the FEE board are two LMR-195 cables with an SMA plug on one side and an N Jack on the other, with the SMA side connected to the FEE board.

Fig.1 Both ends of the LMR-195 Cable

Each cable carries a separate polarization, one north-south, the other east-west. Connected to the N jack is a 9 meter LMR 400 direct burial rated cable with N plugs on both sides.

Fig.2 The mate of the stand and spider cables

All 24 LMR 400 cables, 2 from each of the 12 antennas, connect to the Combiner box which has N type Bulkhead adapter lightning arrestors. Inside of the Combiner box are 6:1 Splitter/Combiners with N type jacks. Each Splitter/Combiner combines one ring, polarization A on one Splitter/Combiner, and polarization B on another. The same occurs with the other ring, which leads to the use of 4 Splitter/Combiners. The bulkheads are connected to the Splitter/Combiners using .085 Semi-Rigid with N type connectors on both sides. Coming out of the Combiner box are 4 N type Bulkhead adapters capped with N type(M) to BNC(F) adapters which are connected to 4 LMR400 trunk line cables with BNC type connections on each end which are 1000 feet in length. These are run underground through 1000 feet of electrical conduit to the control room. After they emerge from the ground they go inside the control room and connect to a plate with 4 N type bulkhead adapters. From the bulkhead runs 4 LMR-195 cables with an N type plug on one end and an SMA plug on the other. This connects to the Analog Receiving(ARX) Board which has 4 SMA jacks in and 4 SMA jacks out. The ARX board prepares the signal for the Analog to Digital Converters(ADC) and the ROACH board, which is the end of the analog signal chain. From the FEE board to the ARX board there is an estimated < 8.23 dB loss due to cable length and the insertion loss of the Combiner Box.

1.2 LoFASM II

The construction is the same for LoFASM II, which is located at the LWA North Arm site, except for the connectors used and the cable lengths for the trunk lines. In all instances where BNC connectors and adapters were used in LoFASM I, LoFASM II uses N type connectors. RG-58 cables were also used instead of LMR-195. At the LoFASM II site the distance from the Antennas to the electronics room only necessitated the use of 550 feet of trunk line. Also, ground screens were installed underneath the antennas to cancel radio waves coming in parallel to the ground by creating an impedance mismatch. Ground screens are to be installed at all sites when all construction is finished. From the FEE board to the ARX board there is an estimated < 5.785 dB loss due to cable length and the insertion loss of the Combiner Box.

1.3 LoFASM III

The construction for LoFASM III will differ slightly from that of LoFASM II in that the RG-58 cable that was used in LoFASM II will be replaced with LMR 195, which is a drop in replacement for RG-58 and is a lower loss cable. The length of trunk line to be used is yet to be determined, as we do not know the distance from the array site and the control room.

1.4 LoFASM IV

As of now, LoFASM IV is to be constructed in the same manner as LoFASM II with the sole exception being the length of trunk line, which differs from site to site due to land constraints.

2 The Antennas

2.1 Construction

The Antennas used in the LoFASM Antenna Array were developed for the Long Wavelength Array(LWA) project for University of New Mexico by the Naval Research Laboratory. For LoFASM we took the Antennas as a black box and designed all of the intermediate and Back End Electronics around the expected signal from the Antenna. The Antenna consists two aluminum dipoles placed orthogonal to each other. They are anchored using Ozposts and aligned with earth's magnetic field. For further information regarding the characterization of the performance of the antennas please refer to the LWA memo series (188).

2.2 FEE Boards

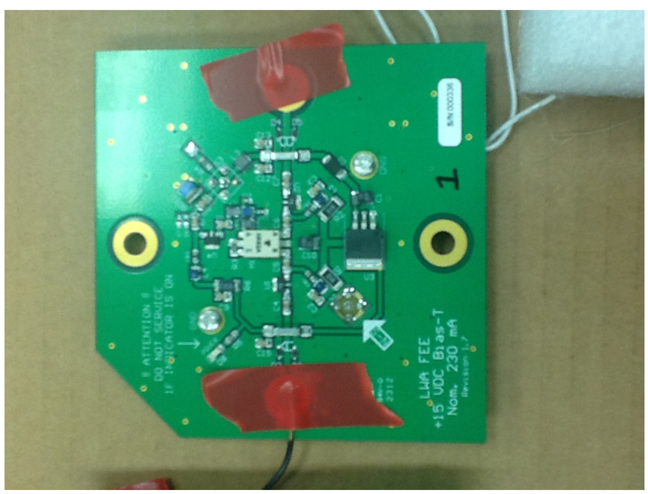

Fig.3 Front End Electronics Board

The FEE boards used in the LoFASM Antenna Array were also developed by the Naval Research Laboratory for the Long Wavelength Array at the University of New Mexico. Characterization of the LoFASM Antenna Array is currently taking place and will be presented in subsequent papers. Below is a summary of the FEE performance as tested by UNM. For more information on the FEE board and a circuit diagram refer to the LWA Memo series (190).

Parameter	Value
Current Draw (at 15 VDC)	230 mA
Voltage Range	±5%
Gain	36 dB
Noise Temperature	250 K
Input 1 Compression Point	-18.3 dBm
Input IP3 Compression Point	-1.8 dBm

3 Combiner Box

3.1 Design

The Combiner box is the point where the signals from the antennas are combined in analog to travel to the control room on 4 trunk lines. The Combiner box sits in between the antennas and the trunk lines and provides protection against lightning strikes. When an antenna is struck, the lightning arrestor bulkheads dissipate the excess charge into the aluminum enclosure and down copper grounding strap to earth ground. This protects the ARX board and the ROACH board from powerful surges that would harm the electronics.

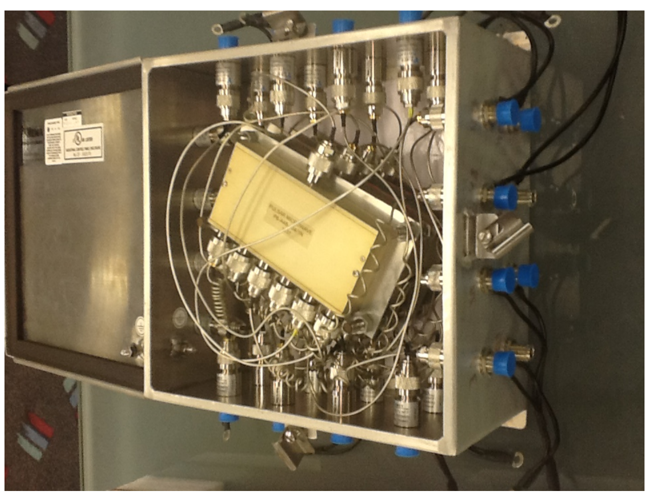

Fig.4 Combiner Box

3.2 Lightning Arrestors

All measurements are from the manufacturer. The characterization of all electronics will be presented in a separate paper.

Electrical Specifications	
Impedance	50 Ω
Frequency Range	DC-700 MHz
VSWR/Return Loss	< 0.2dB(DC-6700 MHz) < 0.3dB(6700-7000 MHz)
Max Surge Current	10kA multiple (8x20us wave-form)
Impulse Sparkover	700V(1kV/us)
Turn on	180 VDC
Average Power	150 Watts
Protection Circuit	DC Pass

Construction Specifications		
Component	**Material**	**Plating**
Body	Aluminum	White Bronze
Inner Conductor	Phosphor Bronze	Silver
Washer	Brass	White Bronze
Coupling Nut	Brass	White Bronze
Insulator	PTFE	N/A
O-Ring	Silicon Rubber	N/A

The theoretical insertion loss through the combiner box as a whole is < 2.38 dB. This accounts for the loss in the bulkhead adapters, intermediate cables, and combiners. A plot of the frequency response can be found in the Combiner Box Technical Memo.

3.3 Splitter/Combiner

The estimated maximum gain through the splitter/combiner due to signal combination is 7.78 dB.

Parameter	Value
Frequency Range	5-300 MHz
Insertion Loss	1.5 dB Max
Isolation	20 dB Min
Amplitude Balance	0.4 dB Max
Phase Balance	5.0 degree Max
VSWR	1.5:1 Max
Input Power	1 Watt Max
DC Pass (All Ports)	1.5 Amps, 15 V

4 ARX Board

The ARX board was developed by the University of New Mexico and modified for LoFASM use. It consists of 4 identical channels, one for each trunk line. Each channel consists of a bias-T to power the FEE, an amplification stage, and a variable filter stage. For greater detail refer to LoFASM technical memo (5).

5 Cables

The values presented in the following tables are all manufacturer's specifications. In house measurements of these parameters will be presented in a separate paper.

5.1 RG-58

Electrical Specifications	
Velocity of Progagation	78% c
Frequency Range	DC-6 GHz
Dialectric Constant	2.3
Impedance	50Ω
Capacitance	26.0(85.3) pF/ft(pF/m)
Jacket Spark	300 VRMS

Insertion Loss		
10 MHz	50 MHz	100 MHz
1.5 dB/100ft	3.5 dB/100ft	4.8 dB/100ft

Construction Specifications	
Inner Conductor	Tinned Copper
Outer Conductor	Tinned Copper Braid
Dialectric	PE
Jacket	PVC

5.2 LMR-400

Electrical Specifications	
Velocity of Progagation	85% c
Frequency Range	DC-6 GHz
Dialectric Constant	1.38
Time Delay	1.2 (3.92) nS/ft (nS/m)
Impedance	50Ω
Capacitance	23.9(78.4)pF/ft(pF/m)
Inductance	0.060(0.20)uH/ft(uH/m)
Sheilding Effectiveness	> 90 dB
Voltage Withstand	2500 VDC
Jacket Spark	300 VRMS
Peak Power	16kW

Insertion Loss		
30 MHz	50 MHz	150 MHz
0.7 dB/100ft	0.9 dB/100ft	1.5 dB/100ft

Construction Specifications		
Description	Material	in(cm)
Inner Conductor	Solid BCCAI	0.108(2.74)
Outer Conductor	Aluminum Tape	0.291(7.39)
Dielectric	Foam PE	0.285(7.24)
Overall Braid	Tinned Copper	0.320(8.13)
Jacket	PE	0.405(10.29)

5.3 .085 Semi-Rigid

Electrical Specifications	
Velocity of Progagation	70% c
Frequency Range	DC-20 GHz
Dielectric Constant	2.1
Impedance	50Ω
Capacitance	29(95.1)pF/ft(pF/m)
Sheilding Effectiveness	> 100 dB

Insertion Loss		
0.5 GHz	1 GHz	10 GHz
0.16 dB/ft	0.22 dB/ft	0.8 dB/ft

Construction Specifications		
Description	Material	in(cm)
Inner Conductor	SPWC	0.02(.508)
Outer Conductor	Tin Dipped Braid	0.0865(2.2)
Dielectric	PTFE	0.066(1.676)
Jacket	N/A	N/A

5.4 LMR-195

Electrical Specifications	
Velocity of Progagation	80% c
Frequency Range	DC-6 GHz
Dialectric Constant	1.38
Time Delay	1.2(3.92)nS/ft(nS/m)
Impedance	50Ω
Capacitance	26 pF/ft
Inductance	0.064(0.21)uH/ft(uH/m)
Sheilding Effectiveness	$>$ 90 dB
Voltage Withstand	1000 VDC
Jacket Spark	3000 VRMS
Peak Power	2.5 kW

Insertion Loss		
30 MHz	50 MHz	150 MHz
1.9 dB/100ft	2.46 dB/100ft	4.3 dB/100ft

Construction Specifications		
Description	Material	in(mm)
Inner Conductor	Solid BC	0.037(.094)
Outer Conductor	Aluminum Tape	0.116(2.95)
Dialectric	Foam PE	0.110(2.79)
Jacket	Black PE	0.195(4.95)

6 Connectors

6.1 BNC

Parameter	**Value**
Frequency Range	DC-4 GHz
Impedance	50 Ω
Body Plating	Nickel
Contact Plating	Gold
Body Material	Brass

6.2 SMA

Parameter	Value
Frequency Range	DC-18 GHz (semi-rigid) DC-12.4 GHz (flexible)
Impedance	50 Ω
Body Plating	Gold
Contact Plating	Gold
Body Material	Brass

6.3 N-Type

Parameter	Value
Frequency Range	DC-11 GHz
Impedance	50 Ω
Body Plating	Nickel
Contact Plating	Gold
Body Material	Brass