

MWA memo
MWA Beamformer Feedback and RFI measurements
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Introduction

Measurements were made in early 2009 of the LNA signals, which when amplified, leak out of the beamformer and “feedback” into the antenna elements producing ripple in the bandpass. Measurements were also made of the RFI generated by the digital control signals in the beamformer. These measurements were made with a high gain beamformer and the original digital control interface, which used a multiconductor cable. In May 2009 the measurements were repeated using a low gain beamformer with modifications to ensure good direct grounding of the SMA inputs and with the new digital over coax (DOC) control interface. The only difference between low and high gain beamformers is the choice of input amplifier for each dipole; the high gain amplifier has ~13 dB more gain.

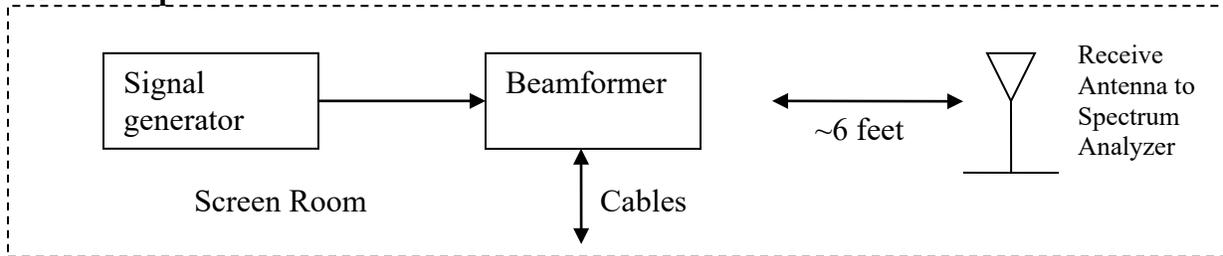
A] Feedback measurements using an unmodified high gain beamformer

A signal generator set at about 150 MHz was connected to the beamformer and the leakage picked-up using a wideband discone antenna connected to a spectrum analyzer. It was determined that the leakage was from 3 sources:

- 1] Common mode leakage from the SMA connectors which were connected to the internal PC board but insulated from the outer box.
- 2] From the amplified signal out of the beamformer – when a single shield RG6 was used but not significantly when a quad shielded RG6 was used.
- 3] From the unshielded power/digital cable connected to the beamformer.

The common mode signals on the SMAs radiated from the LMR-196 coax connected to the beamformer inputs. The radiation tended to be worse for the SMA inputs closest to the power connector. It was observed that this leakage could be reduced when a screwdriver was used to short the SMA to the aluminum front panel of the beamformer. It was also found that the radiation from the power cables could be reduced by keeping the ground wire on the ANU interface board away from the delayline boards. Wrapping the ground wire around the Souriau connector was found to give an additional 5 to 10 dB reduction in the leakage.

Test Setup



Results using the unmodified beamformer with original power/control circuitry

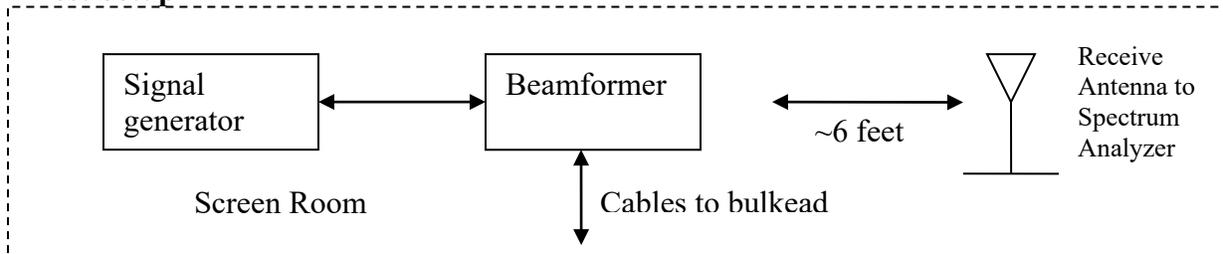
Measurements were done in Feb 2009 on an unmodified (no DOC circuit), high gain unit which had a gain of 33dB and ungrounded SMA inputs. The feedback ratio was:

Single shield RG6	-5dB
Quad shield RG6	-24dB

B| Feedback measurements using a modified beamformer with DOC control

More recent feedback testing was done on a low gain unit that employs the DOC circuitry. As the earlier testing had shown that properly grounding the SMAs to the chassis reduced the feedback significantly, all the SMA connectors on this unit were grounded. No rain shield was installed.

Test Setup



In the screen room a -40dBm signal was fed into the beamformer at 150.1MHz and radiated signal strength was observed using an omni antenna approximately 6ft from the beamformer.

Results using the modified beamformer with DOC interface

The cables to the bulkhead were switched between single shielded and quad shielded RG-6, and the power measured at the omni antenna was:

Single shield RG6	-110dBm
Quad shield RG6	-120dBm

The beamformer under test was a low gain unit and had about 20dB gain. Assuming 16dB gain for the LNA, the feedback ratio is:

Single shield RG6	-54dB
Quad shield RG6	-64dB

Adding loads to the un-used SMA inputs did not appreciably change any readings. In addition, adding 50ft of LMR196 to an unused SMA input did not change any readings.

The expected feed back for a high gain (33dB) unit using the DOC circuit is:

Single shield	-41dB
Quad shield	-51dB

The addition of the painted rain shield degraded the feedback ratio by about 10dB and the expected feedback using it is:

Quad shield, high gain	-41dB
Quad shield, low gain	-54dB

Attaching the spectrum analyzer to an SMA connector yielded a signal that was about -95 to -100dBm which indicates the isolation between the channels on the same polarization is about -55dB to -60dB. The same measurement was made on the other polarization and was below the measurement threshold.

For comparison, previous measurements reported above on an unmodified (no DOC circuit), high gain unit yielded a feedback ratio with quad shield RG6 of:

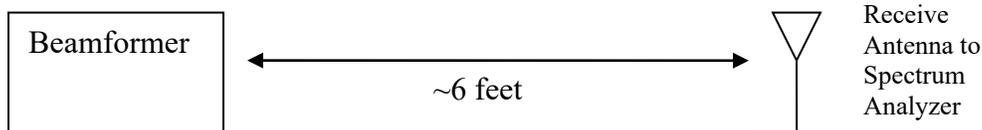
Quad shield RG6	-24dB
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So the improvement which results from the combination of direct grounding of the SMAs, elimination of the leakage from the unshielded power wiring, and the low gain is about 40 dB.

C) RFI measurements with original digital control

Preliminary measurements were taken in Jan 2009 to assess the RFI generated by the digital control logic in the MWA beamformer.

Test Setup (done outside)



The communications computer was set to run continuously so that a maximum level of rfi would be generated. In the normal operation of the beamformer the digital communication will be active at a much lower duty cycle, of order 10^{-5} . The chassis was closed and a short cable to the communication computer was used.

Results

The results at approximately 6ft and extrapolated to 2km are:

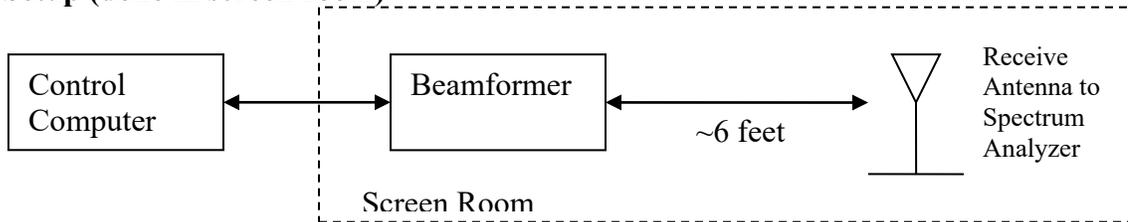
Freq(MHz)	Level at 6ft dBm/1MHz	Level at 2km dBm/Hz
110	-80	-200
140	-75	-195
270	-90	-210
300	-80	-200

A distance to the nearest neighboring RFI sensitive equipment was assumed to be 2km. No additional path loss except free space was assumed.

D) RFI measurements using the new DOC interface

Measurements were taken in May 2009 to assess the RFI generated by the digital control logic in a beamformer that uses the DOC circuit interface.

Test Setup (done in screen room)



The communications computer was again set to run at a 100% duty cycle (compared with $\sim 10^{-5}$ in normal operation) so that a maximum level of rfi would be generated. The control computer signals the beamformer over the output RG-6 cables and is located outside the screen room. A broadband discone antenna, which is strongly coupled in the screen room, was used.

Results

In the 10-300MHz band, except for 33MHz, the received signal from the omnidirectional antenna was below the -166dBm/Hz noise floor of the spectrum analyzer. This implies a power density of -155dBm/Hz/m² at 1-meter wavelength. The corresponding value at 2km, assuming only free space loss, is -215dBm/Hz/m².

The signal at 33MHz, which is about 10dB above the noise floor, appears to be emanating from the PC interface and is strong enough to couple into the screen room. It is present when the beamformer is off.

The -166dBm/Hz upper limit represents an improvement of about 30 dB or more over the previous measurement using an un-modified beamformer.