Digital Radio Seminar
AM HD Radio

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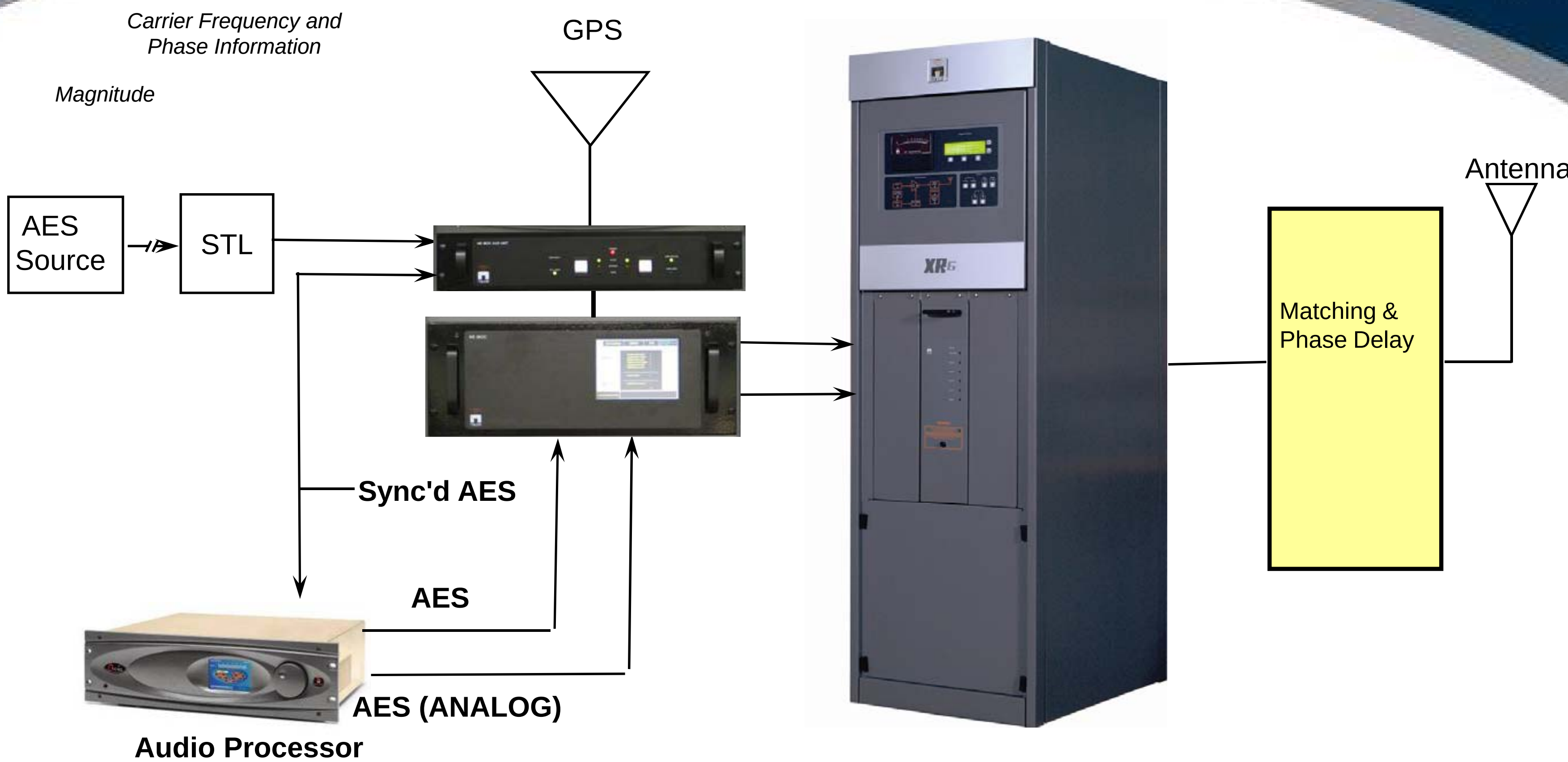
Typical Setup



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Transmitter RF Load Requirements

Step 1 – Determine the RF load characteristics

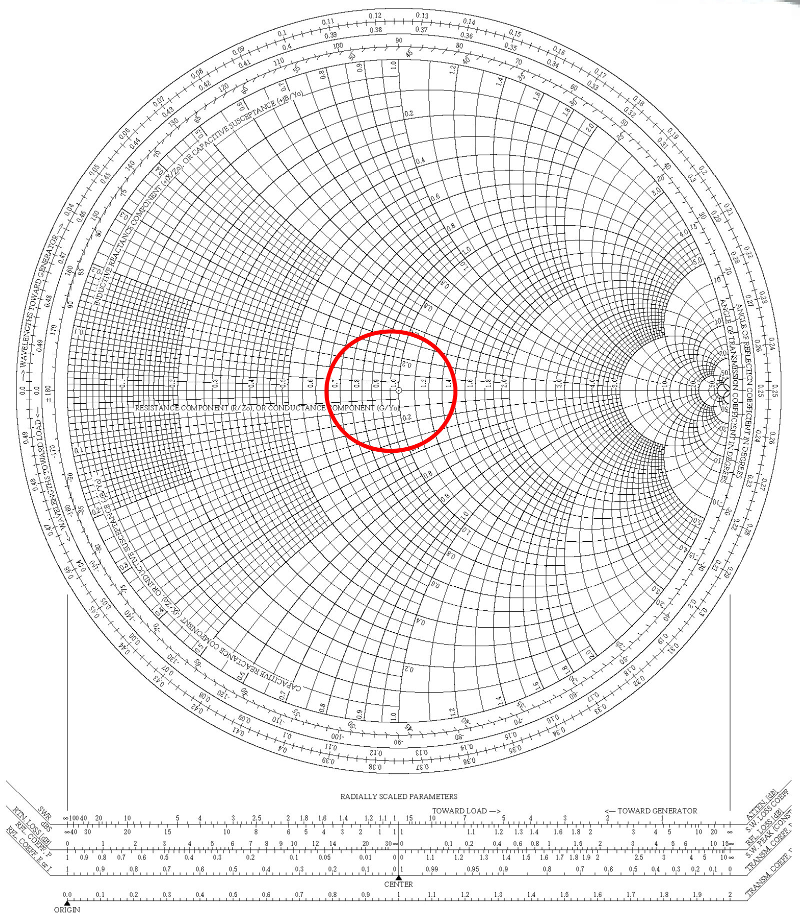
- What does the antenna plot look like?
- What does this load look like to the RF amplifiers?
- What is the delay between the antenna and RF amplifiers?

ANTENNA VSWR

- What does the antenna plot look like over Fc+/- 15 kHz?
- Limits are 1.4:1 at Fc+/- 15 kHz
- Plot should be symmetrical

Antenna VSWR

Smith Chart showing 1.4:1 VSWR Circle



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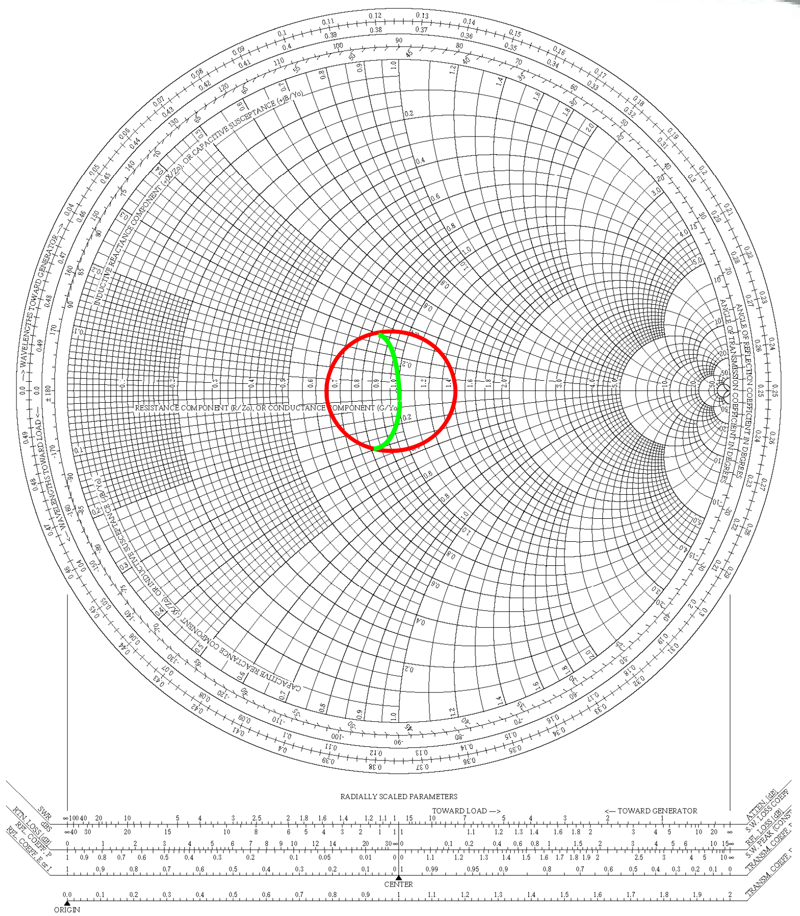
1.4:1 VSWR

Smith Chart showing a Symmetrical load plot.



This is ideal load for amplifiers….not necessarily the same for the output of the transmitter!

Delay through the Transmitter

- How do we determine delay through the transmitter?
- Nautel WEB site – www.nautel.com
- Measure actual delay

www.nautel.com

Information Sheets

Lightning Protection for Radio Transmitter Stations

Recommendations for Transmitter Site Preparation

IBOC Exgine/Exporter/Importer System Guide

FCC AM Specs

FCC FM Specs

FCC Report & Order

Phase Delay vs. Frequency for XR Series Transmitters

Presentations

AM Broadcast Transmitter Site Conversion for HD Radio Transmission

Presented by David Maxon of Broadcast Signal Lab on October 07, 2004 at the NAB Fall Radio Show

This presentation explores the complexities of measuring your IBOC signal. With the addition of a digital waveform to the analog, a host of measurement challenges arise: How do you look at the digital signal carriers? How do you look at occupied bandwidth? How do you know your measurements are meaningful? David presents an overview on how to avoid the traps

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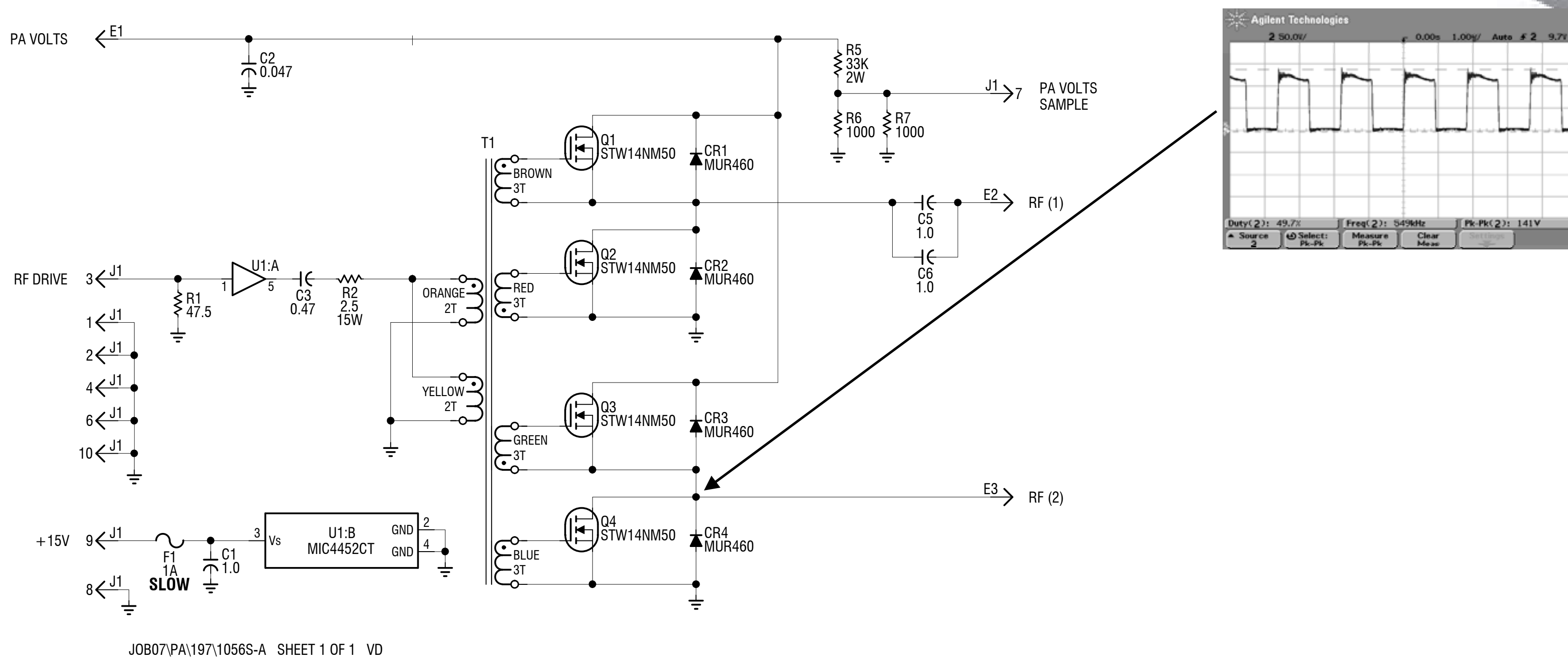
Table 1: XR3 and XR6 Phase Delay vs. Frequency

Freq (kHz)	Phase Delay (°)	Freq (kHz)	Phase Delay (°)	Freq (kHz)	Phase Delay (°)
540	158	930	155	1320	159
550	167	940	158	1330	162
560	154	950	162	1340	164
570	145	960	166	1350	167
580	150	970	172	1360	170
590	156	980	162	1370	174
600	163	990	166	1380	179
610	172	1000	160	1390	162
620	165	1010	164	1400	165
630	151	1020	170	1410	168
640	156	1030	156	1420	172
650	163	1040	159	1430	176
660	154	1050	163	1440	157
670	160	1060	166	1450	159
680	148	1070	170	1460	161
690	152	1080	161	1470	164
700	157	1090	165	1480	166

Phase Delay Measurement

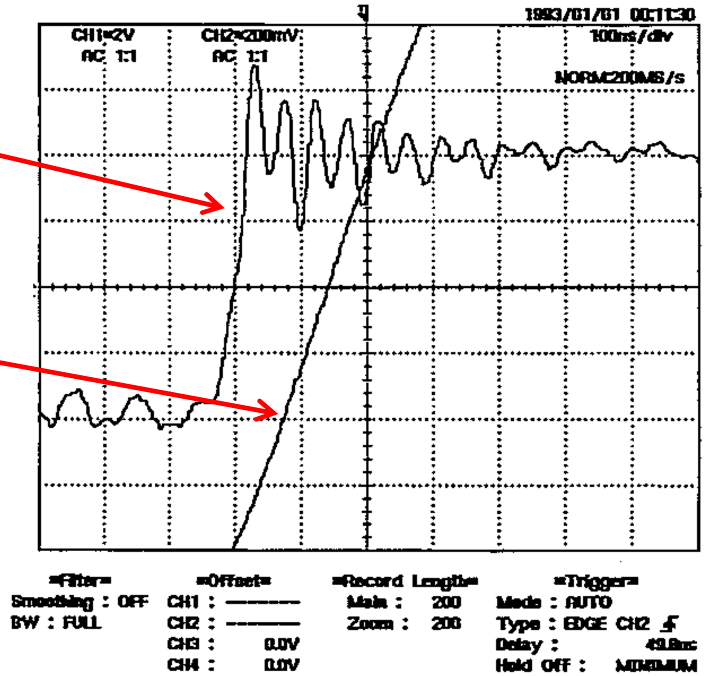


Measure output of RF amplifier and transmitter RF output

Phase Delay Measurement

RF Amplifer Voltage

Rf Output



Phase Delay Correction

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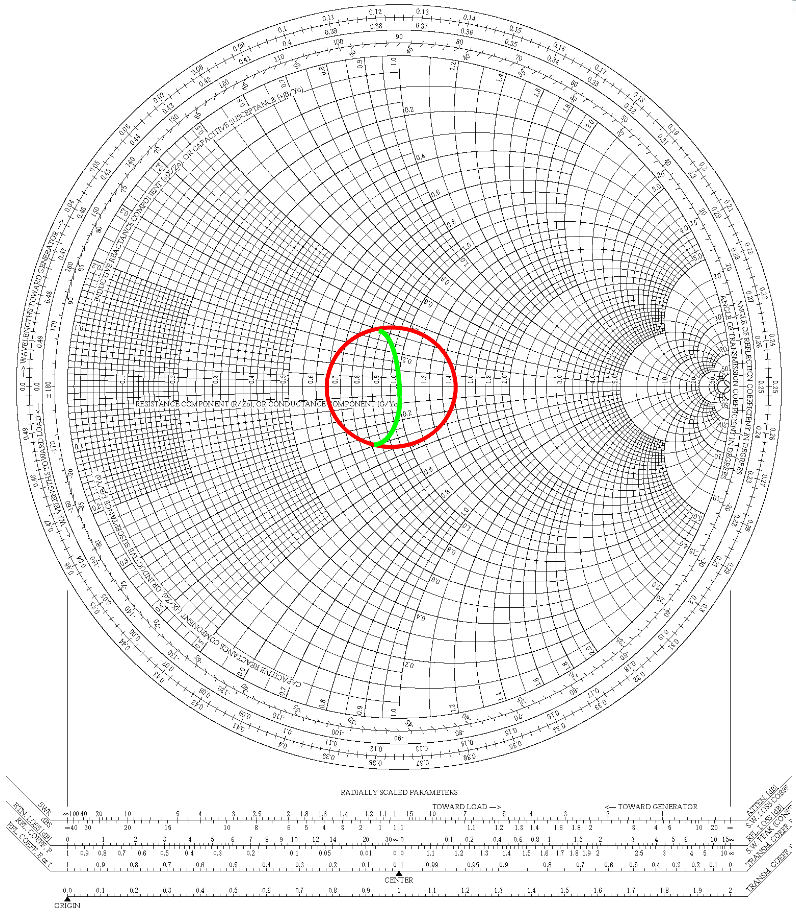
Smith Chart showing a Symmetrical load plot. Let’s assume this load characteristic at the transmitter RF Output

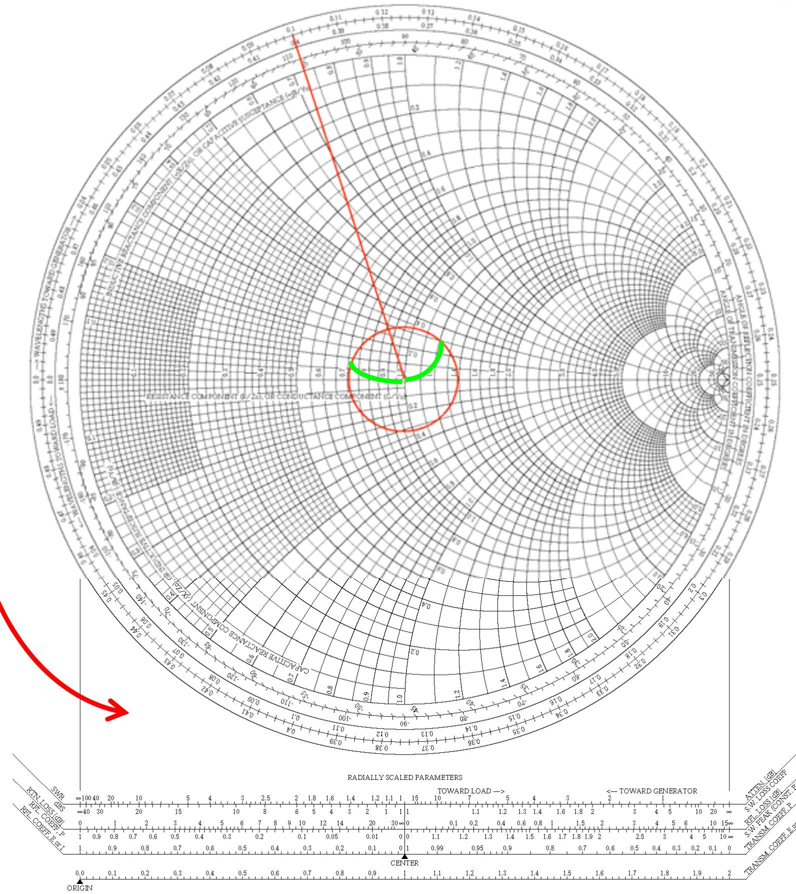


Phase Delay Correction

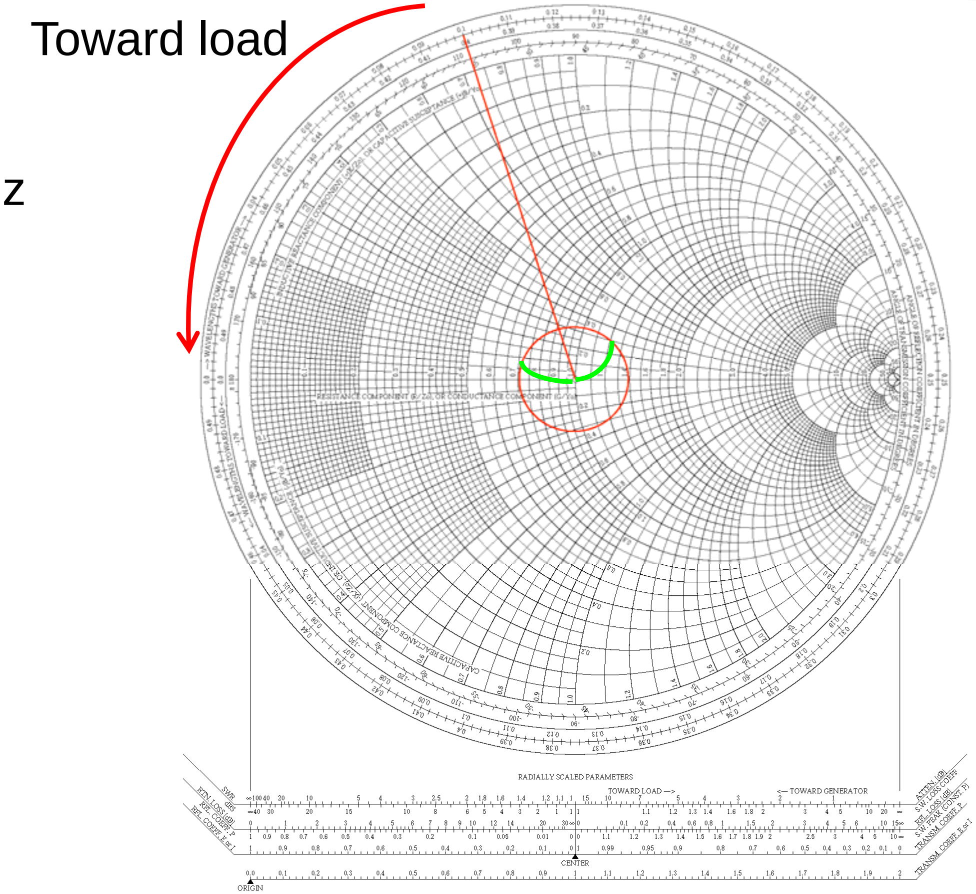
Example for 690 kHz

- 152 degrees delay through RF filter
- Plot shows desired load for output of transmitter

Toward load



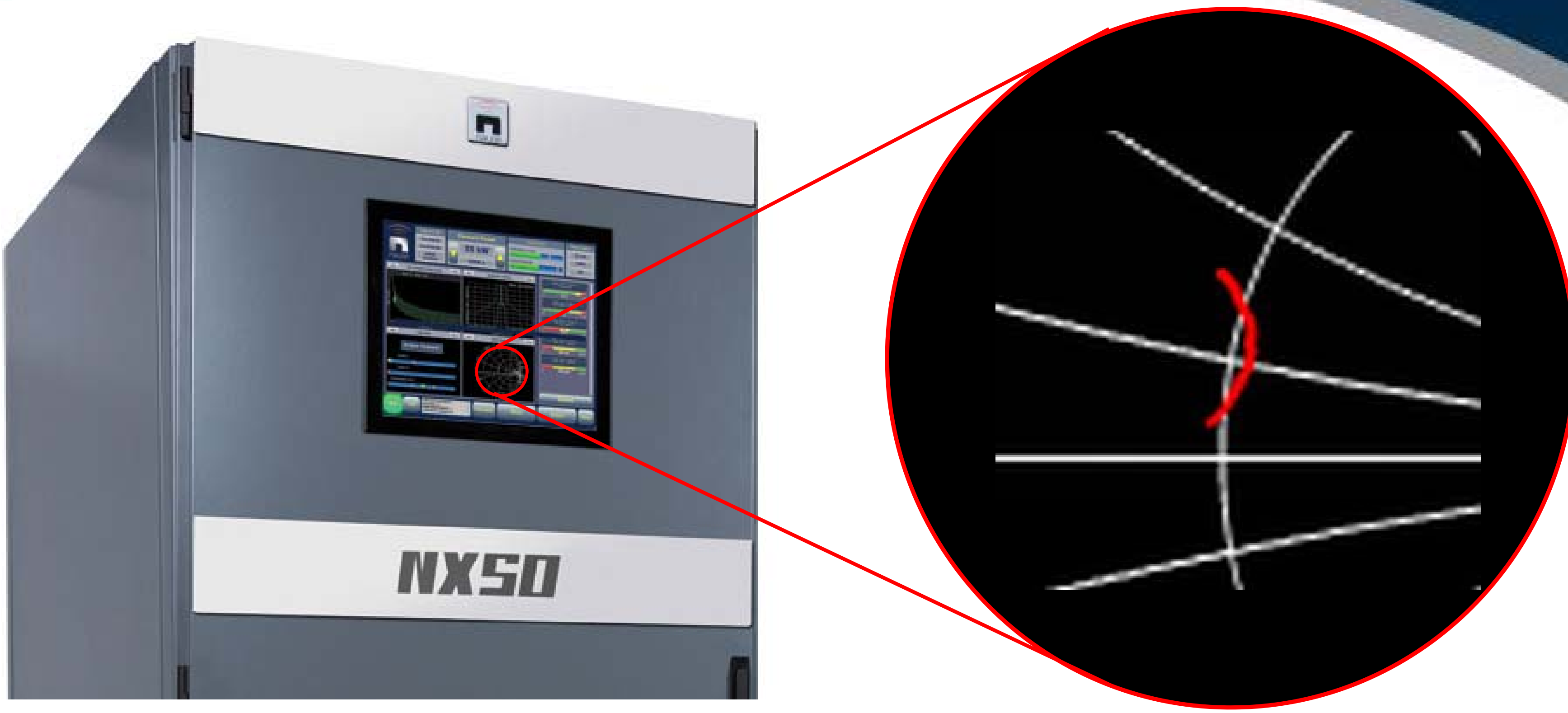
Phase Delay Measurement



Example for 690 kHz

- 28 degrees required between desired and current antenna plot

Phase Delay Measurement



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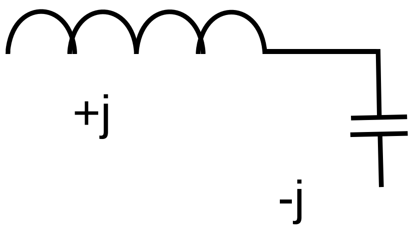
Delay Circuit Design

Design Pi section for 28 degree delay

Delay of ½ Pi section (14 degrees) is = $\tan^{-1} (n-1)^{.5}$, where n is z transform

n=1.062



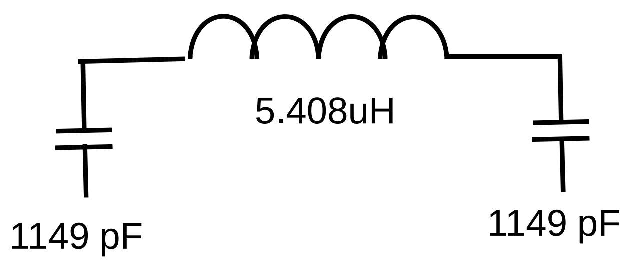
$$+j = 50 \frac{(n-1)^{.5}}{n} = +j11.723$$

$$-j = \frac{50}{(n-1)^{.5}} = -j200$$

Delay Circuit Design

Design Pi section for 28 degree delay

Complete Pi with two LC sections



+j 11.723 * 2 = +j 23.446 = 5.408 uH @ 690 kHz

-j200 = 1149 pF @ 690 kHz

Fine Tuning Options

Transmitter operation can be optimized with pre-correction.

- Measure the transmitter amplitude response into antenna
- Measure transmitter RF Drive phase response into antenna
- Nautel provide pre-correction data for NE IBOC

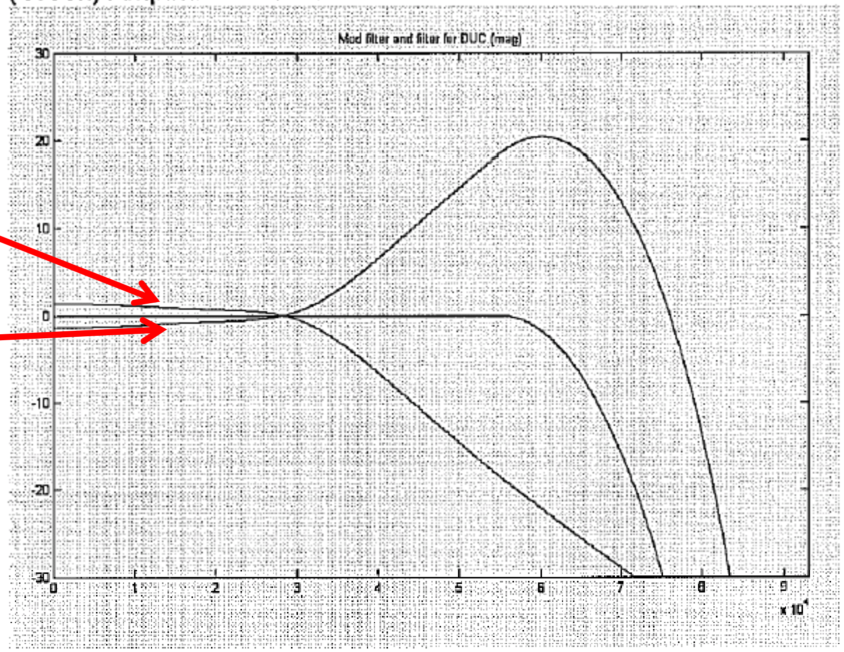
- Newer models have pre-correction designed in

Optimize performance

Transmitter amplitude response measured into 50 ohm load

Pre-correction response created

Figure 2: (Blue) Transmitter Modulation Amplitude Response into 50 ohms
(Green) Amplitude correction curve for DUC



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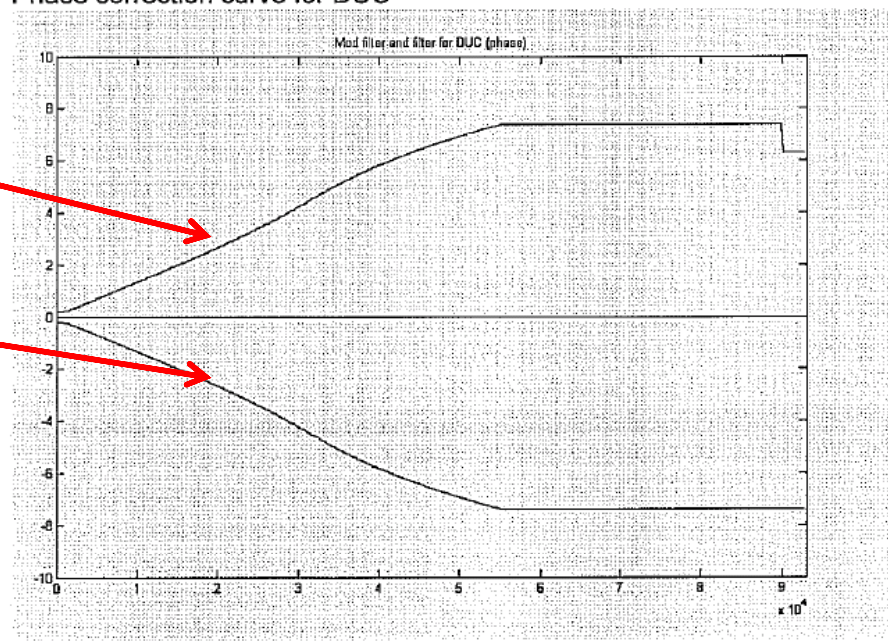
Transmitter Phase response measured into 50 ohm load

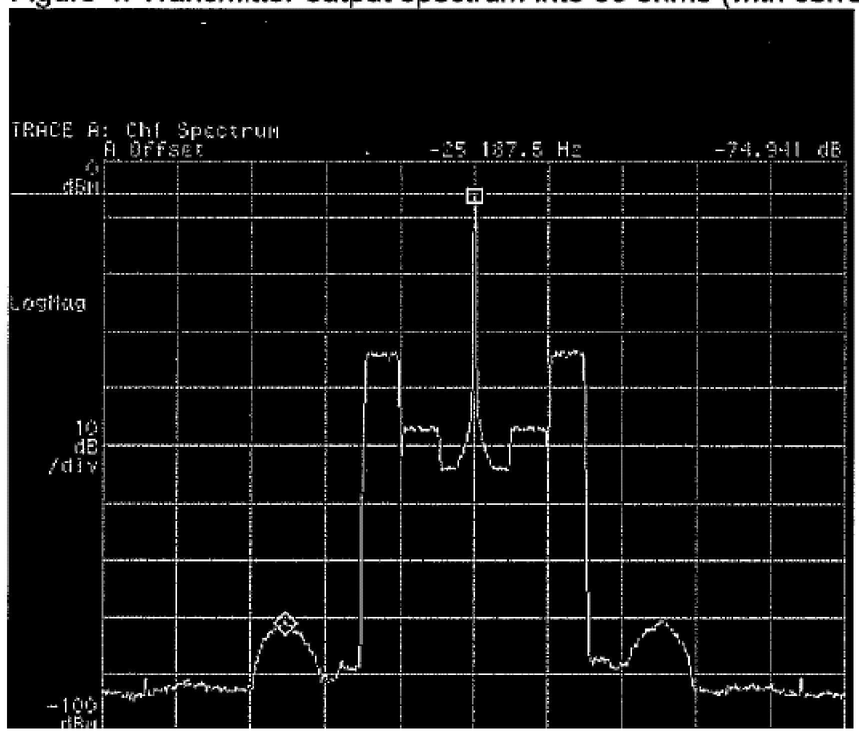
Pre-correction response created

Figure 3: (Blue) Transmitter Modulation Phase Response into 50 ohms, (Green) Phase correction curve for DUC



Spectrum shows excellent reduction in Intermodulation re-growth

Figure 4: Transmitter output spectrum into 50 ohms (with correction; No Mod)



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Antenna optimization

Transmitter amplitude response measured into antenna

Pre-correction response created

Figure 5: (Blue) Transmitter Modulation Amplitude Response into tuned load, (Green) Amplitude correction curve for DUC

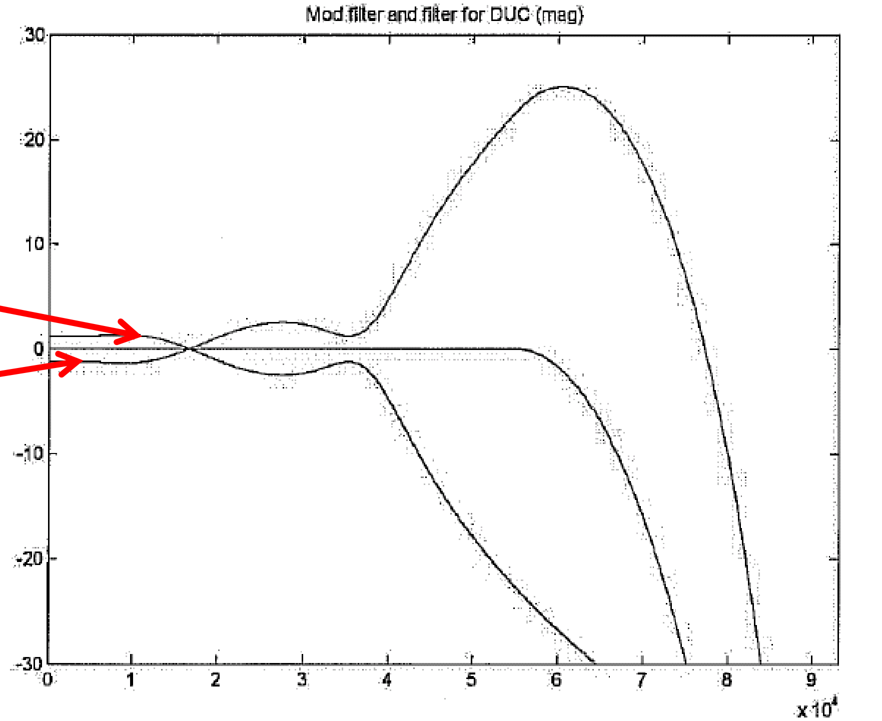

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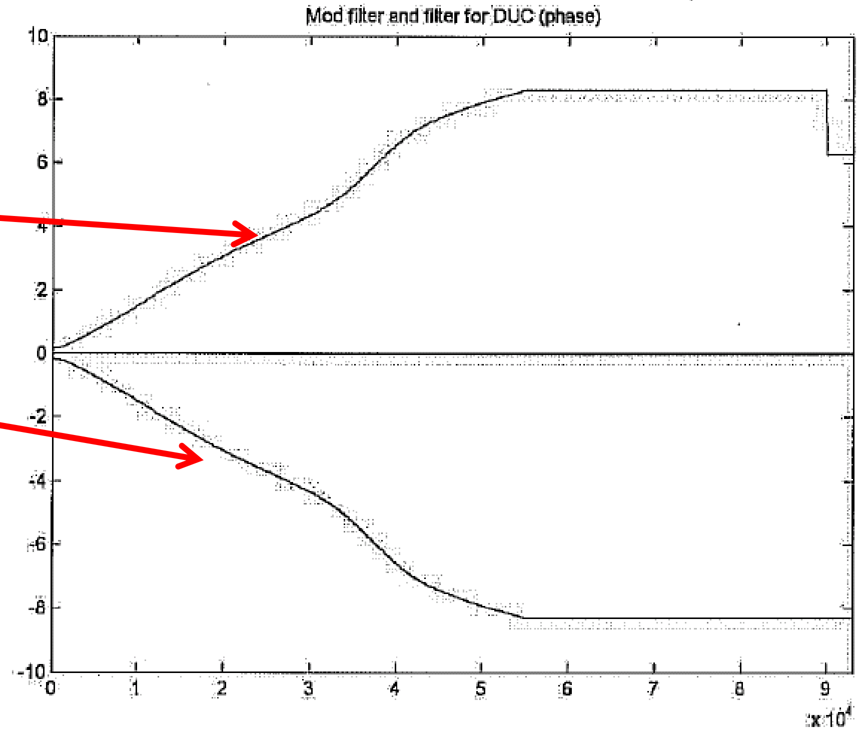
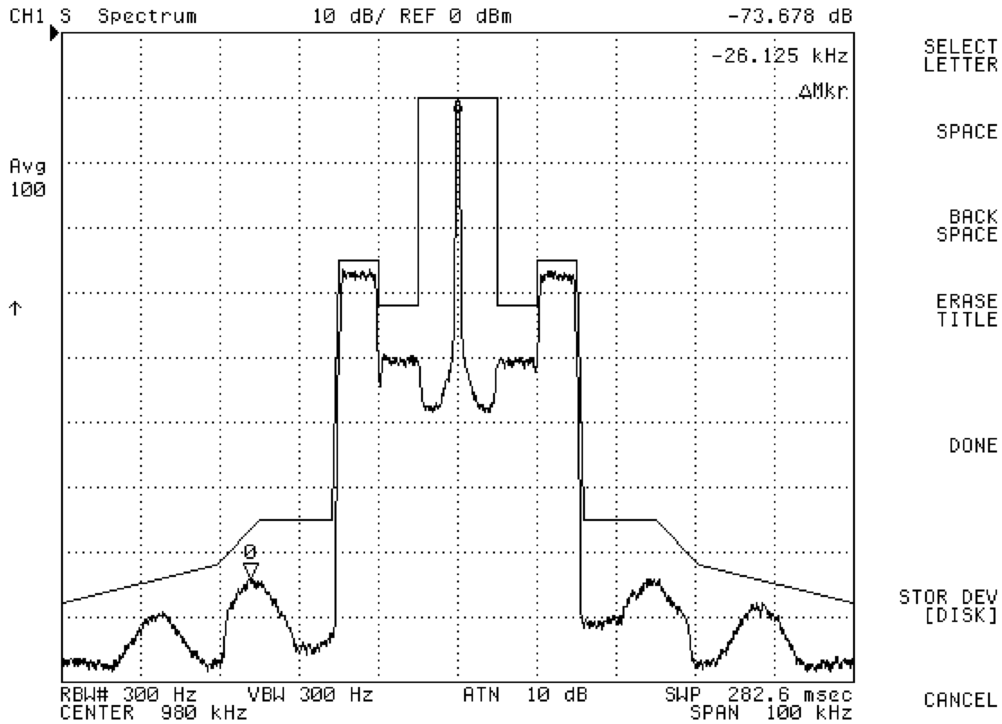
Figure 6: (Blue) Transmitter Modulation Phase Response into tuned load, (Green) Phase correction curve for DUC



Transmitter Phase response measured into antenna

Pre-correction response created

Spectrum of transmitter into antenna model at Nautel showing a good margin of safety with reference to the emissions mask



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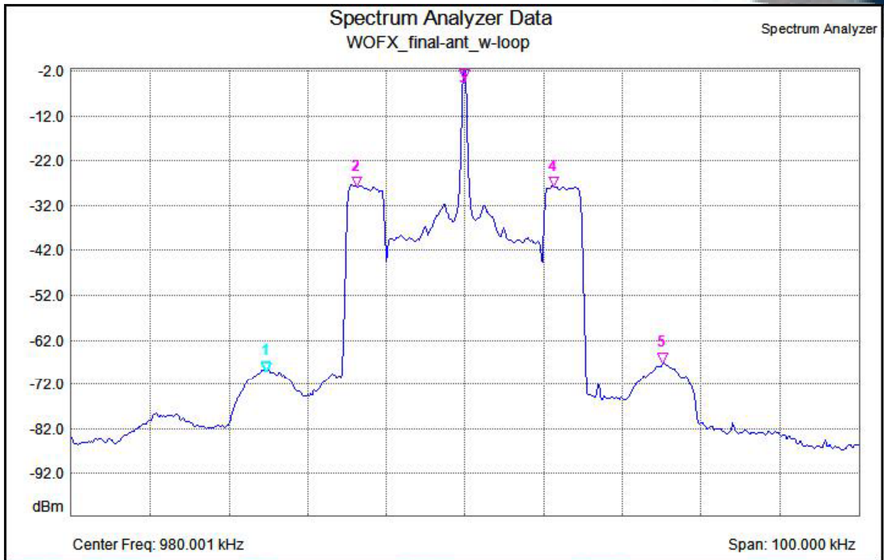
On Air Performance

Spectrum of transmitter into actual antenna showing a satisfactory margin of safety with reference to the emissions mask



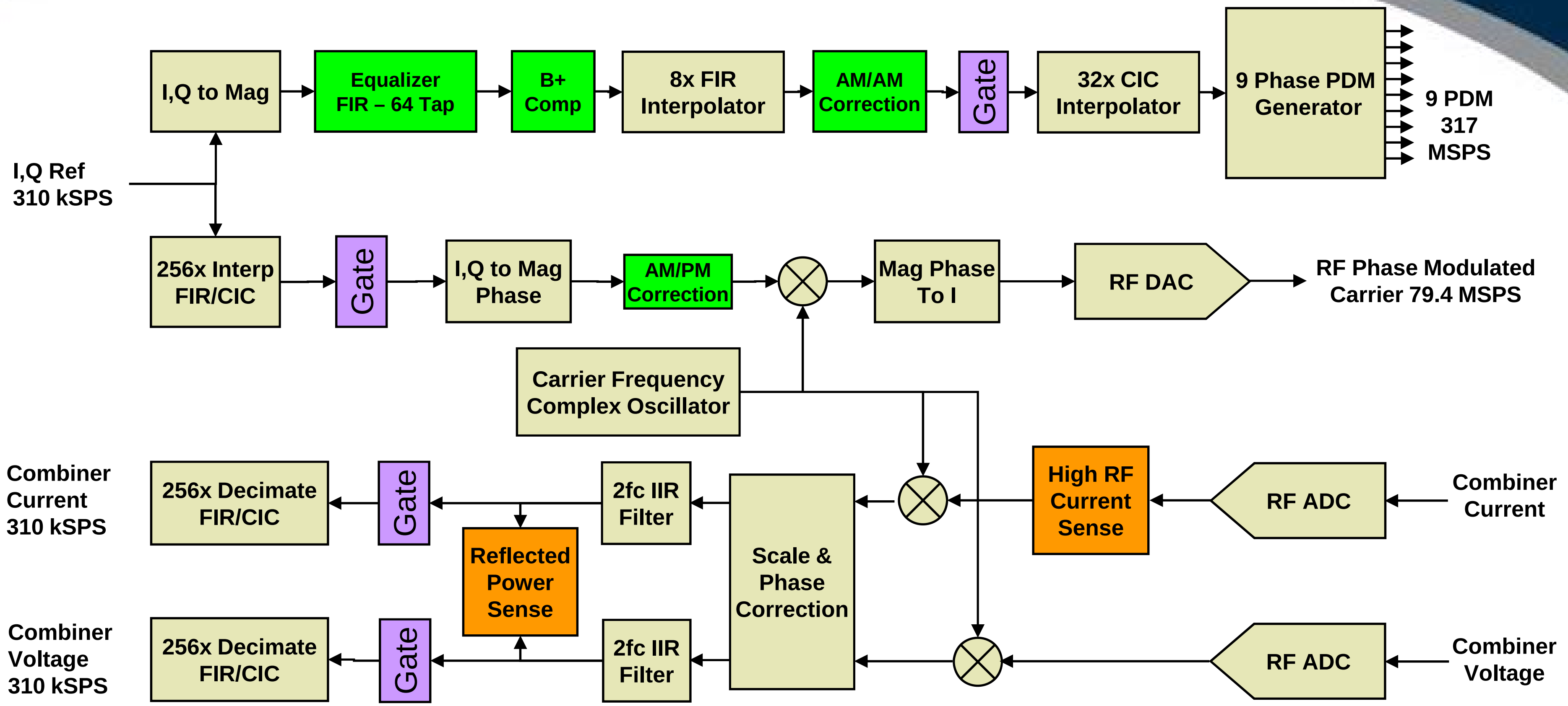
Mkr	Ref	Delta	Ref Freq	Ref Amp	Delta Freq	Delta Amp
1	■	□	954.727 0 kHz	-69.06 dBm	- -	- -
2	□	□	966.182 0 kHz	-27.86 dBm	- -	- -
3	□	□	980.000 0 kHz	0.21 dBm	- -	- -
4	□	□	991.273 0 kHz	-27.91 dBm	- -	- -
5	□	□	1.005 1 MHz	-67.11 dBm	- -	- -
6	□	□	- -	- -	- -	- -

Measurement Parameters

Trace Mode	Average	Center Frequency	980.000 kHz
Trace Average	50	Start Frequency	930.000 kHz
Reference Level Offset	-1.5 dB	Stop Frequency	1.030 MHz
Input Attenuation	30.0 dB	Frequency Span	100.000 kHz
RBW	300.0 Hz	Reference Level	-1.473 dBm
VBW	100.0 Hz	Scale	10.0 dBm/div
Detection	Sample		

Spectrum using loop antenna

FPGA Block Diagram



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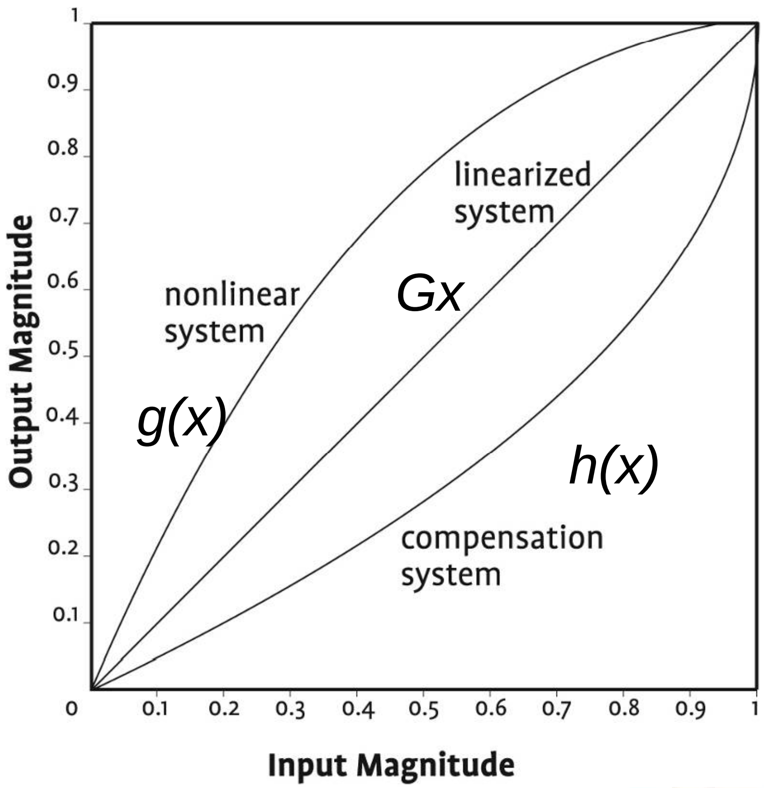
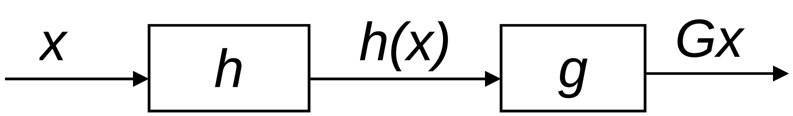
Pre-Correction Principle



An amplifier characteristic $g(x)$ may be corrected for with a complementary characteristic $h(x)$ such that $g(h(x)) = Gx$

For this to be true, $G\,h(x) = g^{-1}(x)$



Pre-Correction Features

The FPGA has three correction sections in the forward path:

Envelope equalization: Corrects for filtering effects in the modulator (envelope magnitude and phase response versus frequency)

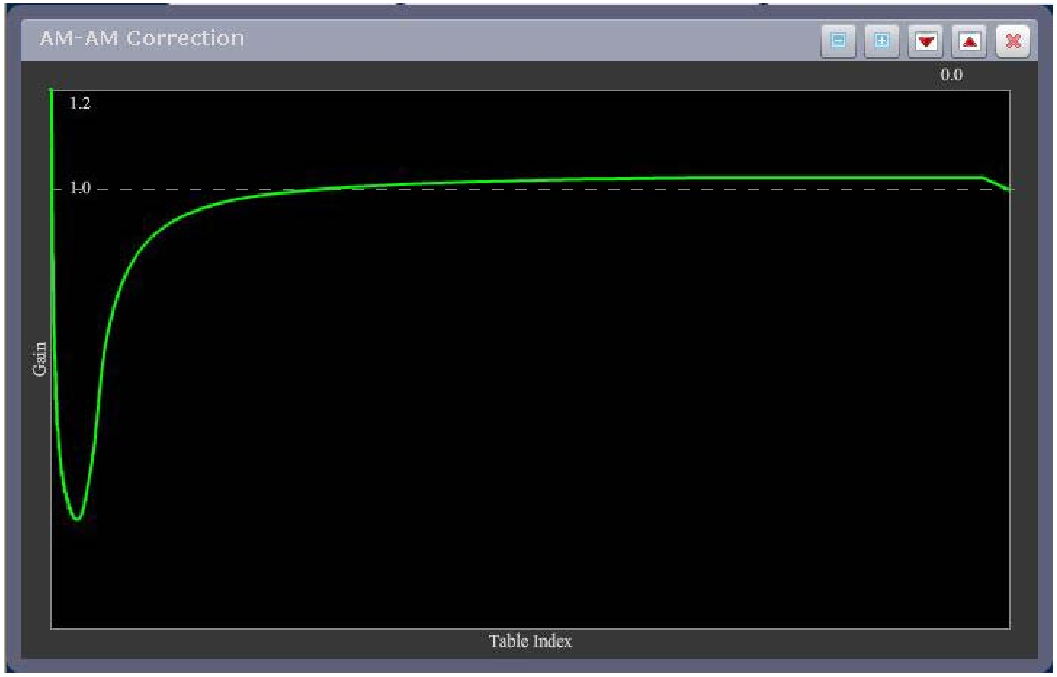
AM/AM Correction: Corrects for amplitude error in the modulator due to capacitive effects in the FET. (Essentially AM distortion)

AM/PM Correction: Corrects for phase error in the RF amplifier due to capacitive effects in the RF FET. (IQM or IPM effects)

Additionally it will be possible to correct for linear effects in the AM antenna system using a filter in the DSP

Typical Correction Curves AM/AM

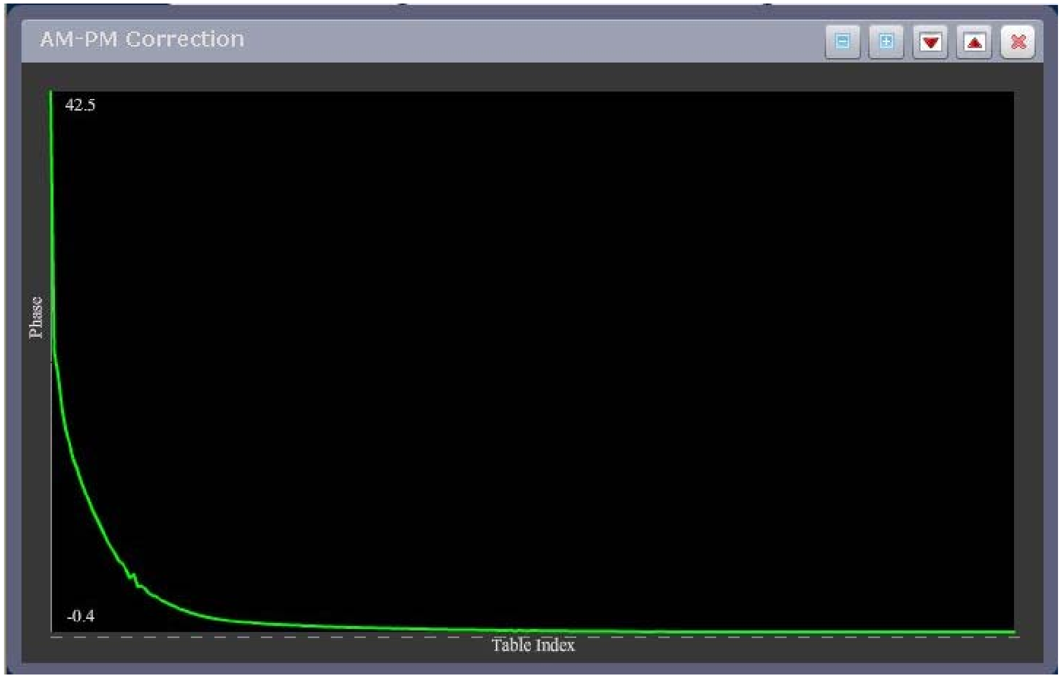
Gain



Envelope Voltage

Typical Correction Curves AM/PM

Phase Correction



Envelope Voltage

Conclusions

- A fundamental requirement to broadcast the HD Radio signal is to present a symmetrical load to the RF amplifiers with Hermitian symmetry.
- A further improvement to the system linearity can be made by providing correction data curves for the transmitter amplitude and phase responses.
- Technology improvements are making measurement much simpler on the transmitter end, reducing test equipment requirements and making optimization easier.
- Improvements in pre-correction can also help.