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TITLE: INTERMODULATION RFI IN RADIOMETER SYSTEMS

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INTERMODUCATION RFI IN RADIOMETER SYSTEMS

William D. Brundage

Even though strong Radio Frequency Interference (RFI) signals may be outside the nominal bandpass of a radiometer system, and may not be visible on a monitoring spectrum analyzer, the RFI signals may contaminate the system data. RFI caused by intermodulation within a radiometer system has occurred at Green Bank. Only occasionally has the cause been recognized and corrected. This note discusses the conditions which produce intermodulation RFI, discusses cures, and describes a specific case of such RFI.

Intermodulation

Two (or more) signals which are within the radiometer system will produce spurious signals if at least one signal is at a power level in the non-linear range of an amplifier or mixer. The spurious frequencies f_{IM} are produced according to

$$f_{IM} = |mf_x \pm nf_y| \quad \text{where } m = 0, 1, 2, \ldots \text{ and } n = 0, 1, 2, \ldots$$

Second order f_{IM} occurs where $m + n = 2$ and third order f_{IM} occurs where $m + n = 3$. The special case of harmonic f_{IM} occurs where either m or $n = 0$ and n or $m \geq 2$.

Effects

If any intermod product f_{IM} is produced with sufficient amplitude and frequency to appear at the square-law detector of a continuum radiometer or in the passband of a spectrometer (autocorrelator, filter bank, etc.), it will cause visible RFI, such as birdies in an autocorrelator spectrum. Note that at least one high-level signal and one or more other signals must be present in a non-linear element in order to produce significant intermod products of order 2 or higher.

Very wide "baseband" and octave-plus wide Intermediate Frequency (IF) systems are especially susceptible to harmonic RFI birdies. In a non-linear IF element, a high-level RFI signal at the low-frequency end of the IF passband can generate harmonics which fall within the autocorrelator passband.

Cures

In radiometer designs and retrofits, intermodulation, harmonic and other non-linear effects will be minimized if the "operating dynamic range" is as large as possible at every point throughout the RF and IF signal path between feed and detector/sampler. Here "operating dynamic range" is defined as the ratio of the 1 dB gain-compression power to the total wide-band power integrated over 0 to ∞ frequency. Total wide-band power includes noise and peak RFI signal power (as in radar pulses). The ratio should exceed 20 dB. Among other things, this means that the gain ahead of the bandpass filter(s) which reduce a RFI signal should be as low as possible and the 1 dB gain-compression power should be as high as possible.

Image stopband filtering must be adequate as mixers will "pass" RFI signals in the image band. This can be a problem in multi-frequency-conversion systems. First LO frequencies should be above or below the RF band to place the image band in the "quieter" RF range. Because $f_{image} = f_{RF} \pm f_{IF}$, the IF frequency passband should be reasonably high and the IF bandpass filters should have steep skirts and -60 dB stopbands without spurious responses.

An Example of Intermod RFI

In November, 1981, the new 21 cm cooled-FET radiometer on the 300-ft experienced RFI birdies in the autocorrelator spectra. Known possible RFI sources were:

RFI Source

1255.76 MHz, ± 3.5 MHz sidebands	FAA radar	30 dB peak*
1292.01 MHz, ± 3.5 MHz sidebands	FAA radar	30 dB peak*
1297.3 MHz, ± 0.5 MHz sidebands (May be moved to 1300.0 MHz.)	Link GB to 45-ft	40 dB*
1317.5 MHz	Interferometer (85-ft) LO	3 dB*
1347.4 MHz	Link 45-ft to GB	40 dB*
1347.5 MHz	Interferometer (85-ft) LO	20 dB*
1347.6 MHz	Link GB to 45-ft	40 dB*

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* dB of signal above noise in 50-400 MHz IF band on spectrum analyzer.

A very strong birdie appeared at velocity (optical definition) of ∿ 4780 km/s only in C-channel for at least 7 sources of F. Mirabel's observing. See Figure 1. Other birdies appeared at velocities ∿ 9300 and ∿ 12 600 km/s.

After many attempts to accurately measure frequencies of RFI signals at RF and IF, the birdies were traced to intermodulation in the 40-500 MHz IF input amplifier/mixer of channel C IF Processor.

The ∿ 4780 km/s birdie was produced by the 1297.3 and 1347.4/1347.6 MHz link signals intermodulating in channel C IF Processor.

$$\underline{f_{LO}} - \underline{f_{RF}} = \underline{f_{IF}}$$

$$1550.86 \text{ MHz} - 1297.3 \text{ MHz} = 253.56 \text{ MHz} = f_y$$

$$1550.86 \text{ MHz} - 1347.4 \text{ MHz} = 203.46 \text{ MHz} = f_{x\,1}$$

$$1550.86 \text{ MHz} - 1347.6 \text{ MHz} = 203.26 \text{ MHz} = f_{x\,2}$$

$$f_{IM\,1} = |2*(203.46) - 253.56| = 153.36 \text{ MHz} \rightarrow \sim 4780 \text{ km/s}$$

$$f_{IM\,2} = |2*(203.26) - 253.56| = 152.96 \text{ MHz} \rightarrow \sim 4780 \text{ km/s}$$

where

$$f_{IF} = 151.00 \text{ MHz} \rightarrow 4400 \text{ km/s}.$$

See Figure 1 annotations.

Channel C intermodulation birdies were "cured" by reducing the IF input power level by 20 dB to match the channel A input power level. For the 21 cm receiver, the IF Processor input attenuators should be set at 30 dB instead of 10 dB. Intermod products were reduced further by putting 22 to 60 MHz wide bandpass filters between the IF Processor input attenuators and amplifiers to eliminate at least one of the strong RFI signals.

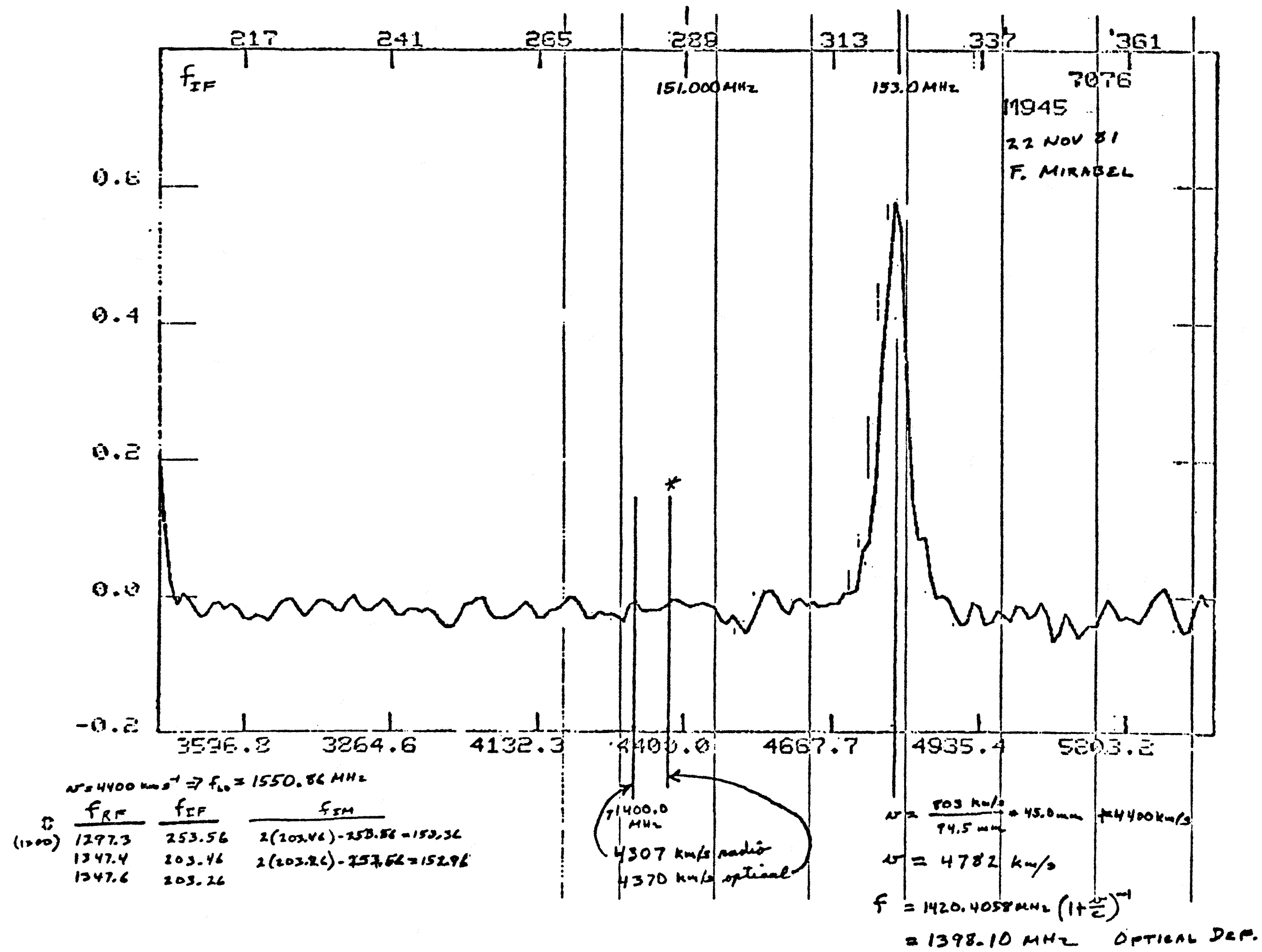

FIGURE 1