BEACONS & FM ID

Presented to
50 MHz and Up Group

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Background

- January 2022 a work party went to Mt. Allison
- Installed 10 GHz beacon and translator
- This has been used many times, including a monthly net.
- Installed 80 GHz beacon
- It was heard from various places
- BUT in June, it was not heard at places where it had previously had a strong signal.

Background

- After much deliberation a crew went to Allison in September.
- Oliver, KB6BA, brought a spectrum analyzer and found the beacon was about 40 kHz low in frequency.

Confirming Beacons

- In October, Oliver, KB6BA and Paul, AA6PZ spent a long afternoon at Don Edwards verifying the beacons.
- Oliver brought rubidium standards, a frequency synthesizer and a spectrum analyzer.
- Paul brought transverters for 80, 47 and 24 GHz

Frequency Test Method

- Oliver's equipment generated an accuate reference frequency in the 47 and 80 GHz bands.
- Starting with 80 GHz, the baseband rig was an FT-817 in USB. It was tuned, by ear, for zero beat. The frequency reference signal was used to compute the actual beacon frequency.
- This was repeated using IC-705 and tuning for zero frequency in the water fall display.
- The 47 GHz transverter has an IF outside of Amateur Bands, so only the 705 was used.
- There was no frequency reference for 24 GHz.

Frequency Results

80 GHz

FT-817	80831.95906 MHz
IC-705	80831.95896 MHz
Difference	100 Hz

47 GHz

IC-705	47087.9999 MHz

Signal Strength Test

- The spectrum analyzer was used in place of the baseband radio.
- First tuned away from the signal
- Measure noise floor.
- Tune in the beacon and measure signal strength

Signal Strength Test

Frequency, GHz	Signal, dBm	Noise Floor, dBm	SNR, dB
80	-68	-123	55
47	-92	-126	34
24	-79	-133	54

- Video Bandwidth = 3 kHz

But There Was More

- In monitoring 47 GHz, it was observed that the frequency wasn’t stable. It was wandering up and down more than 100 Hz.
- After some thinking and several experiments, the problem was found to be the OCXO which was exposed the breeze.
- An enclosure of plastic foam stabilized the frequency.

And Yet Another Puzzle

- During some of the excursions to test the 47 GHz frequency stability, the voice ID was not heard. It was heard at Don Edwards, but not at Baylands.
- Could the problem be that the signal was just enough weaker that the FM voice was not demodulated?

Review of Modulation

- Frequency modulation and phase modulation are close cousins.

Review of Modulation

- Example, carrier frequency 1 MHz.
- Period is 1 μS.
- So, in 1 μS the phase goes through 360 degrees or 2π radians.
- If the frequency is changed (modulated) the rate of change of phase also changes.

Review of Modulation

- If the modulation is a single tone, it is impossible to tell the difference between FM and PM.
- If the modulating frequency is increased, FM will have the same deviation. If the modulator is PM, the deviation will increase.
- But this can be “corrected” by shaping the frequency response of the modulating signal.

Review of Modulation

- Virtually all FM transmitters boost the higher audio frequencies. (pre-emphasis)
- FM receivers have a compensating de-emphasis circuit.
- Together, the desired audio is correct and high frequency noise is reduced.

Review of Modulation

- A phase modulator with appropriate adjustment of the audio spectrum can create proper FM.
- One possible block diagram is to first synthesize a stable carrier frequency. Put that through a PLL and inject the desired modulation into the PLL.

Demodulation

- Three stages.
- IF amplifier with appropriate bandwidth.
- Limiter stage that removes amplitude variations.
- Detector stage recovers the audio.

Demodulation

- Common detectors:
- Discriminator consisting of L’s and C’s to give amplitude related to the instantaneous frequency.
- PLL phase detector output is the audio.

Demodulation

- It is “well known” that strong FM signals have a recovered signal with a very good SNR.
- For weak signals, the audio SNR is worse than AM (or CW or SSB).
- Lot’s of general descriptions, but hard to find detailed information.

Demodulation

- There were a lot of rainy days this winter so I had a lot of time to search.
- Eventually found a thesis written 50 years ago by man at Bell Labs working toward his master’s degree.

Mathematical Derivation

- Starting with noisy signal:
- $V(t) = [A_c + A_N(t)] \cos[\omega_c t + \Phi(t)]$
- We can derive the probability of

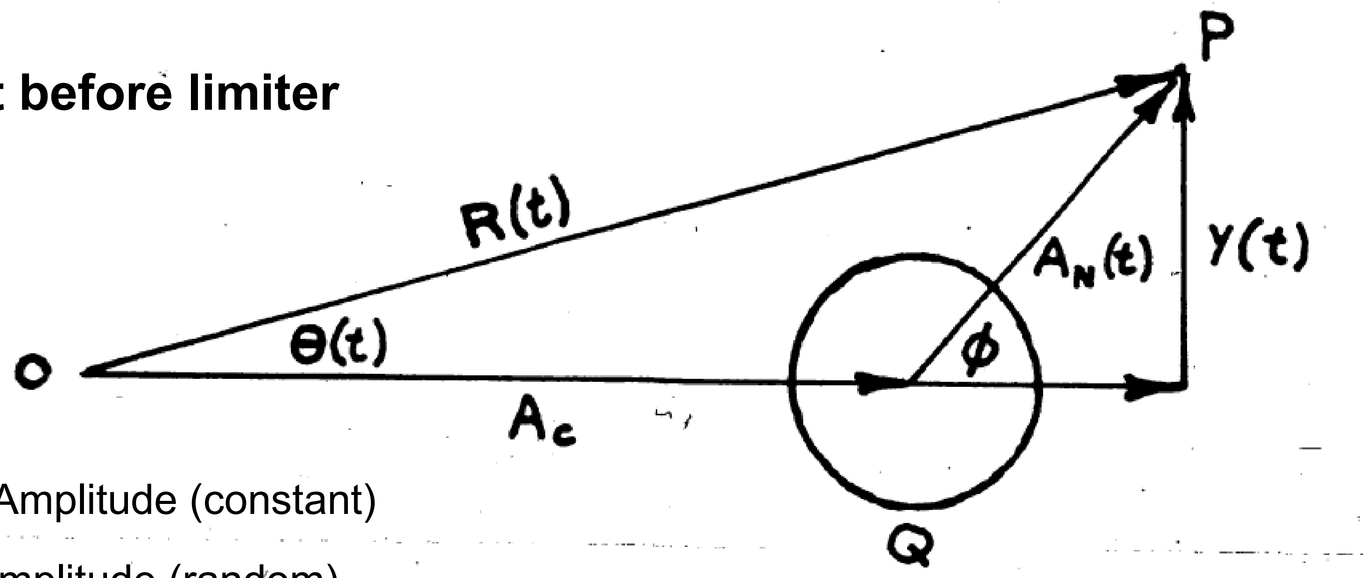
$$p(R)dR = \frac{1}{2\pi\sigma^2} \int_R^{R+dR} \int_0^{2\pi} e^{-r^2/2\sigma^2} r\,d\phi\,dr$$

- Which can be simplified to:

$$p(R) = \frac{R}{\sigma^2} e^{-R^2/2\sigma^2}$$

Vector Representation

- **IF output before limiter**



- A_c Carrier Amplitude (constant)
- A_n Noise Amplitude (random)
- Φ Noise phase, Uniform between 0 and 2π
- R Composite result

Three Regions

- Ac >> An   Very little noise after the limiter
-             (Full Quieting)
- A_c ~= A_n Threshold region
- A_c << A_n SNR worse after detector

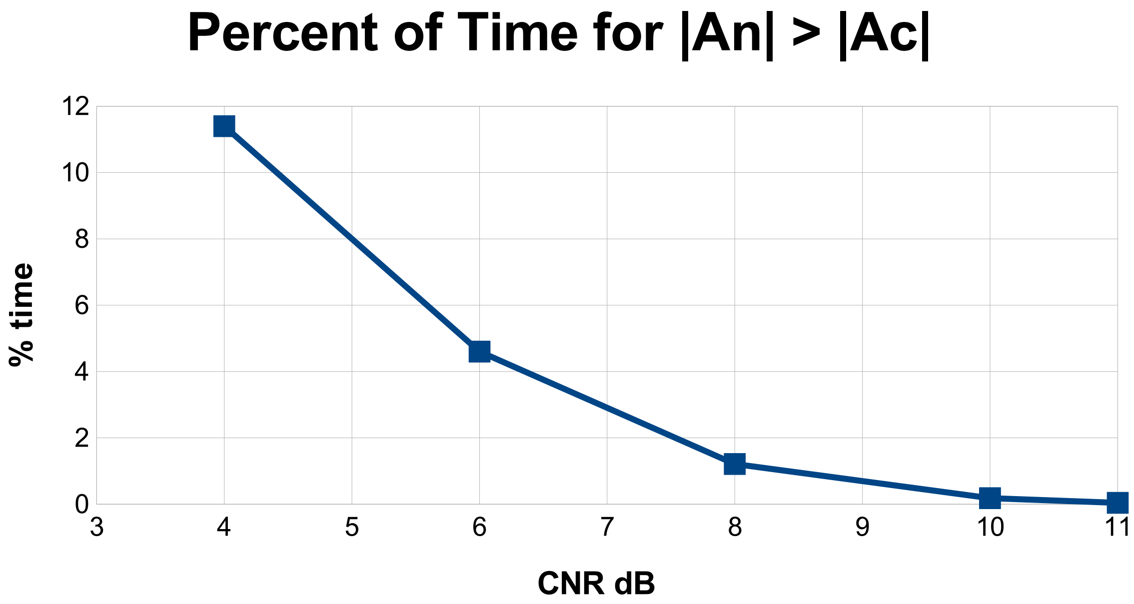
Threshold Region

- Noise is random. Occasionally there will be noise peaks equal to the carrier, even though the noise RMS is much less.
- For CNR 8dB, this happens about 1 % of the time.

CNR, dB	% Time |An| > Ac	Ac / AN RMS
11	0.04	12.6
10	0.18	10.0
8	1.21	6.3
6	4.6	4.0
4	11.4	2.5

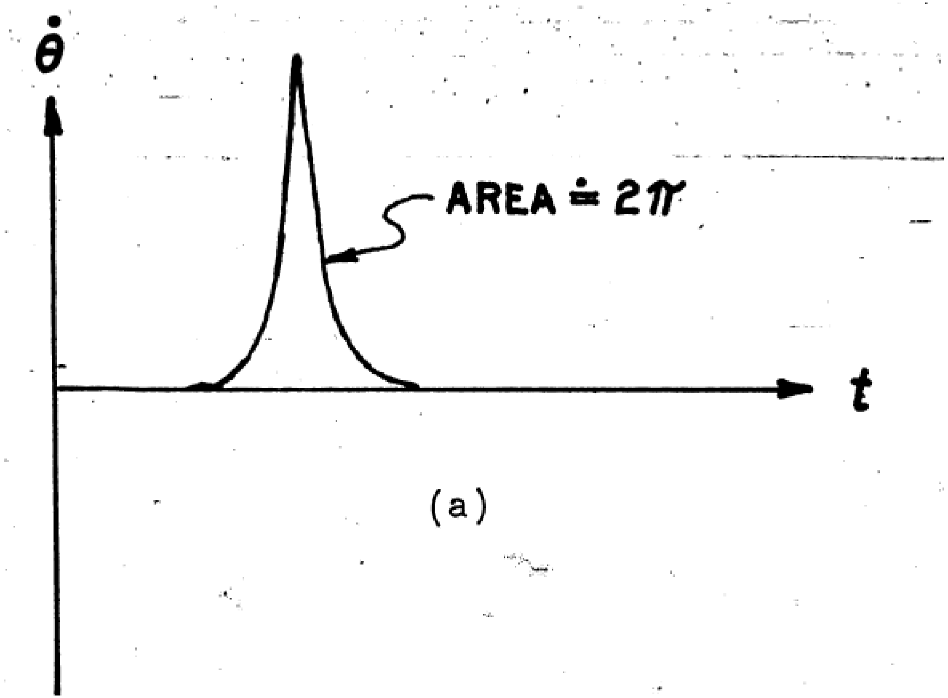
Threshold Region

- Small changes in CNR have major effect how often the noise exceeds the carrier.



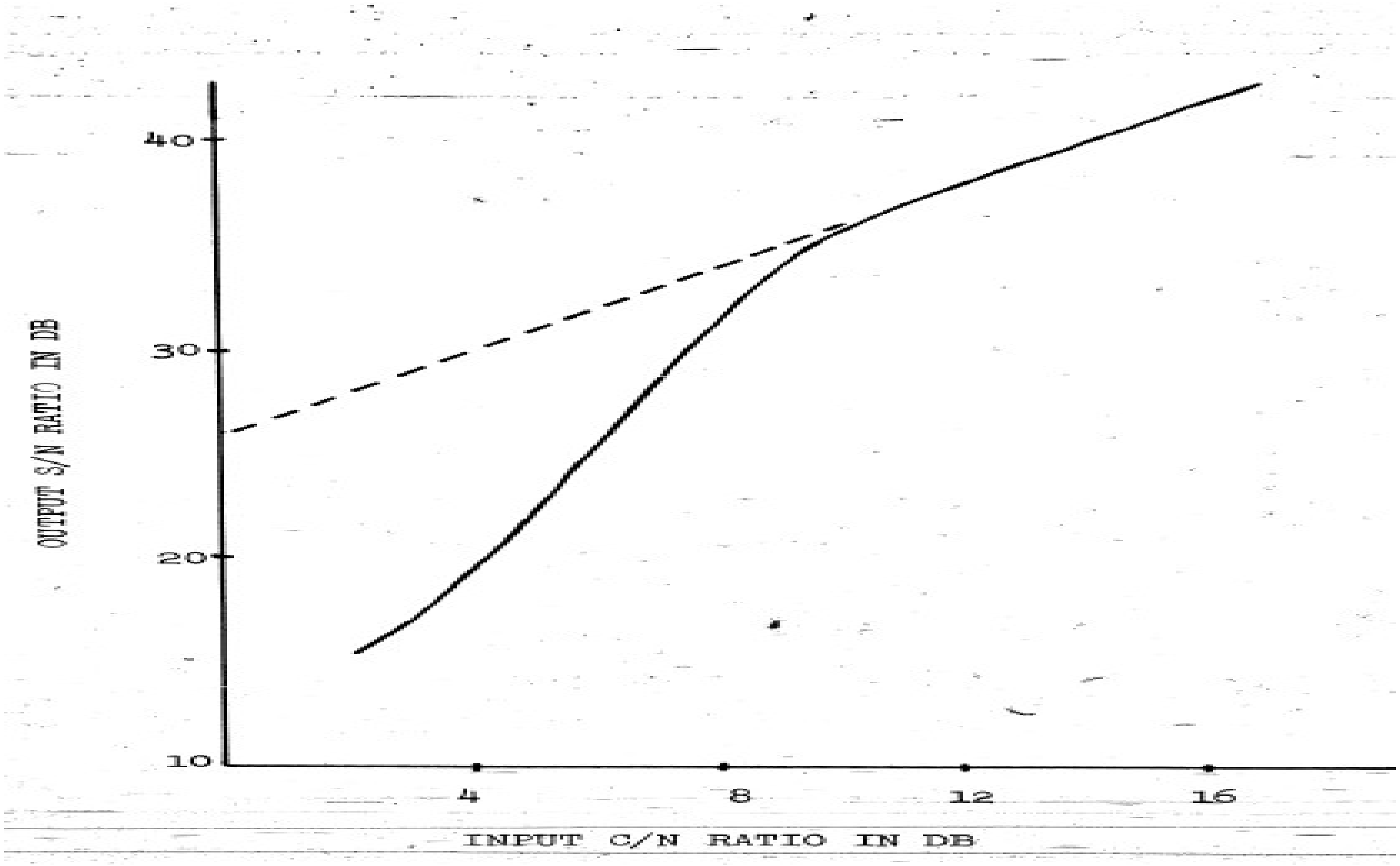
Noise Pulses

$A_n > A_c$
Φ passes through π radians
Θ changes by 2π radians
Audible clicks



(a)

Effect of CNR



24 GHz Experiments

- Finally had a break in the WX
- Go to Baylands with SDR to measure CNR.
- WX calm, high thin clouds, almost no breeze
- Started with Leeson 24 GHz.
- With dish peaked, CNR ~ 16 dB. Voice ID: full quieting.
- Change dish pointing slightly to get lower CNR.
- 2-3 dB QSB on carrier.

24 GHz Experiments

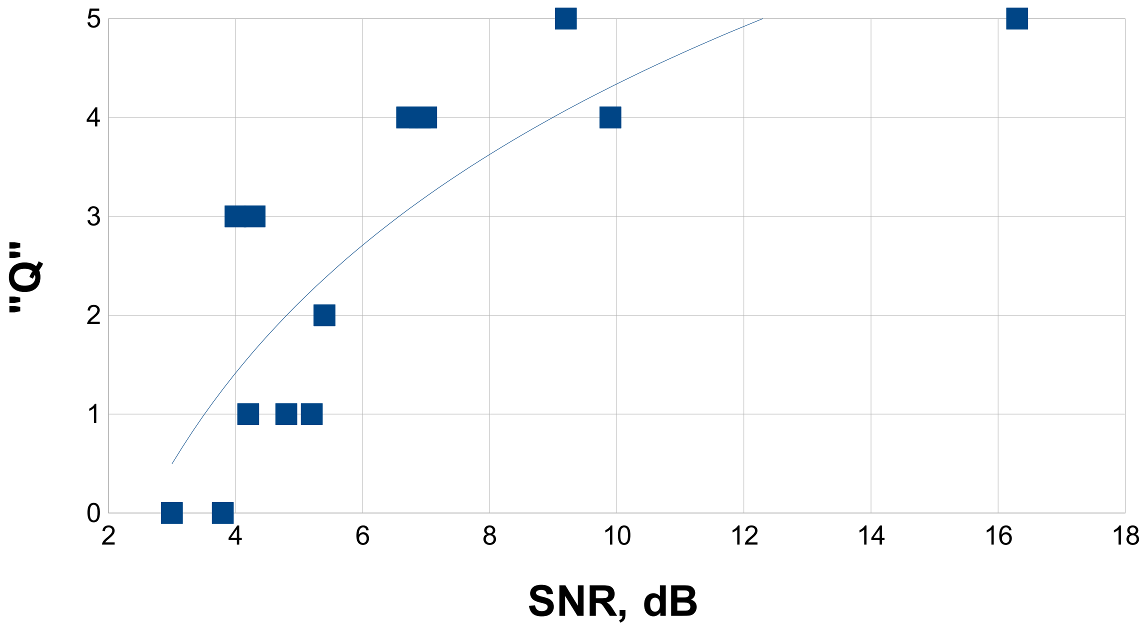
- The QSB made it impossible to get good data.
- CNR changing 3 dB or more in a period of 10 seconds.
- Part of ID might be good copy; and part very hard to pick out.
- Maybe this is caused by fluttering leaves in front of the beacon?
- While waiting / hoping for signals to stabilize, I decided the way to evaluate the voice was the traditional ham Q scale (0-5).

47 GHz Experiments

- Point dish to Allison 24GHz, steady signal with CW ID
- QSY to 47 GHz
- Carrier strength very steady, only a fraction of dB changes.
- Measure CNR.
- Evaluate Q of the voice ID on the “Q” scale from 0 to 5.
- Move dish small amount
- Repeat
- IF BW 8 kHz (lowest preset value for Narrow Band FM)

47 GHz Experiments

- Clicks most noticeable for between SNR 8 and 10 dB



47 GHz Experiments

- FM was reasonably intelligible for SNR above 5 dB.
- Discernible at even lower levels.
- So why did I not hear voice ID on previous occasions?

47 GHz Experiments

- So why did I not hear voice ID on previous occasions?
- Several beacons with CW ID that repeats every 30 seconds.
- Leeson FM ID repeats every 60 seconds.
- Allison 47 FM ID repeats ~ 90 seconds.
- Most likely I simply had not been waiting long enough!

Next Step?

- Everyone who can hear beacons from some convenient location should keep a record of frequency, signal strength and quality. Maybe it's just humidity absorbing RF signals, or maybe a repair is indicated.
- In particular, how common is the QSB on Leeson 24? Perhaps it was something in the atmosphere that day. Maybe it's always like that. Either way, it's good to know.
- In the unlikely event that I run out of other activities, it would be good to repeat the 47 G experiment and collect more data.
- Also check beacons with different deviation, that is if there are times when steady carriers are heard from Leeson.

Reference

Lehigh Preserve Institutional Repository

Threshold characteristics of frequency modulation noise

Ludinsky, Charles J.
1969

- The full document is here: Threshold Characteristics of frequency modulation noise