What does Auto Tune actually do?

- It helps us to calibrate our VARA FM Station
- **Definition of a calibrated VARA FM Station:**
  - A calibrated VARA FM station is first, a station that has set its **Transmit Audio Drive Level** so that its receive Signal-to-Noise (S/N) ratio at the distant end station is adequate to recover the message data.
  - And second, a calibrated VARA FM station is also a station that has set its **Receive Audio Drive Level** so that it can recover the distant end station's message data.

- **Transmit Audio Drive Level**
  - The transmit audio drive level must be set to not overdrive or underdrive the audio signal that modulates the carrier.
  - An overdriven transmit audio signal will spread the FM carrier bandwidth out beyond the detection bandwidth of the receiver and thus reduces the receive signal level needed to successfully demodulate and decode the digital data.
  - The VARA FM Terminal Node Controller AUTO TUNE operation assists you in setting the transmit audio drive level
- **Receive Audio Drive Level**
  - The receive audio level must be set to not overdrive the Analog-to-Digital Converter (ADC) which is the soundcard chip.

Auto Tune sets the Frequency Deviation (F_{dev}) of the FM Carrier

What is F_{dev} ?

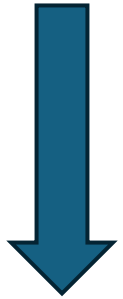
F_{dev} is a variable that defines the highest and lowest transmitted frequency of the FM carrier.

That is, it defines the transmission bandwidth of the FM carrier

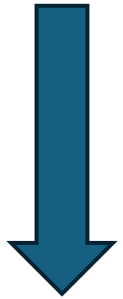
What controls the F_{dev} ?

- ANSWER: the Transmit Audio Drive Level

Transmit Audio Drive Level *sets the*



FM Carrier ***Frequency Deviation*** *which in turn*



defines the ***FM Transmission Bandwidth***

This can be illustrated using Carson's Rule
The FM Carrier Bandwidth is approximated by Carson's Rule

Carson's Rule: $BW_{FM\ TX} = 2 \times (\text{highest voice frequency} + F_{dev})$

F_{dev} = Frequency deviation which dictates the highest & lowest frequency of the Frequency Modulated carrier

And, it is the **Transmit Audio Drive Level** that sets the **Frequency Deviation**

In amateur radio mobile and HT voice communications the F_{dev} typically does not exceed 5 kHz

If the highest voice frequency is 3 kHz, using Carson's Rule

$$BW_{FM\,TX} = 2 \times (3\ kHz + 5\ kHz)$$

$$BW_{FM\,TX} = 16\ kHz$$

Where, the highest transmitted frequency = (Fc + 8 kHz)

And the lowest frequency transmitted frequency = (Fc – 8 kHz)

Typical amateur FM radios support 15 kHz – 16 kHz voice transmissions

VARA FM Winlink data communications uses the same mobile and HT rigs we amateurs use for voice communications

Therefore, the VARA FM Winlink transmission bandwidth must stay in the same 15 kHz to 16 kHz range so that the data message can be successfully recovered at the receiving station.

Carson's Rule applies to VARA FM Winlink data communications

Carson's Rule: $BW_{FM\ TX} = 2 \times (\text{Baseband Audio BW} + F_{dev})$

What is the VARA FM Winlink Baseband Bandwidth?

Specifically, what is the VARA FM NARROW Baseband Bandwidth?

We'll address the VARA FM WIDE Baseband Bandwidth, later.

Deriving the VARA FM Winlink Baseband Audio Bandwidth
Baseband Audio BW = (symbol rate) x (number of carriers)

- The bandwidth of the modulated audio carrier is approximately = symbol rate
- VARA FM NARROW Level 11
  - There are 58 modulated audio carriers being transmitted simultaneously during a message transmission.
  - The 58 carriers are Orthogonally Frequency Division Multiplexed (OFDM) together.
- Level 11 Baseband Audio BW ≈ 2500 Hz
- Baseband Audio BW = 42 Hz x 58 carriers
- Baseband Audio BW = 2436 Hz
- Maximum VARA FM NARROW Baseband BW with guard band on he left and right will be approximately 2500 Hz

VARA FM Speed Table

	VARA FM WIDE				VARA FM NARROW			
Level	Symbol Rate	Carriers	Mod.	Net Rate (bps)	Symbol Rate	Carriers	Mod.	Net Rate (bps)
1	42	14	4PSK	566	42	14	4PSK	566
2	42	29	4PSK	1188	42	29	4PSK	1188
3	42	58	4PSK	2390	42	58	4PSK	2390
4	42	98	4PSK	4040	42	58	4PSK	3188
5	42	98	4PSK	5387	42	58	8QAM	4252
6	42	98	8QAM	7185	42	58	16QAM	5668
7	42	98	16QAM	9580	42	58	32QAM	7087
8	42	116	16QAM	11340	42	58	64QAM	8505
9	42	116	32QAM	14144	42	58	64QAM	9567
10	42	116	64QAM	16932	42	58	128QAM	11162
11	42	116	64QAM	19003	42	58	256QAM	12750
12	42	116	128QAM	22102				
13	42	116	256QAM	25210				

For VARA FM NARROW communications the frequency deviation should not exceed 5 kHz

Therefore, using Carson's Rule

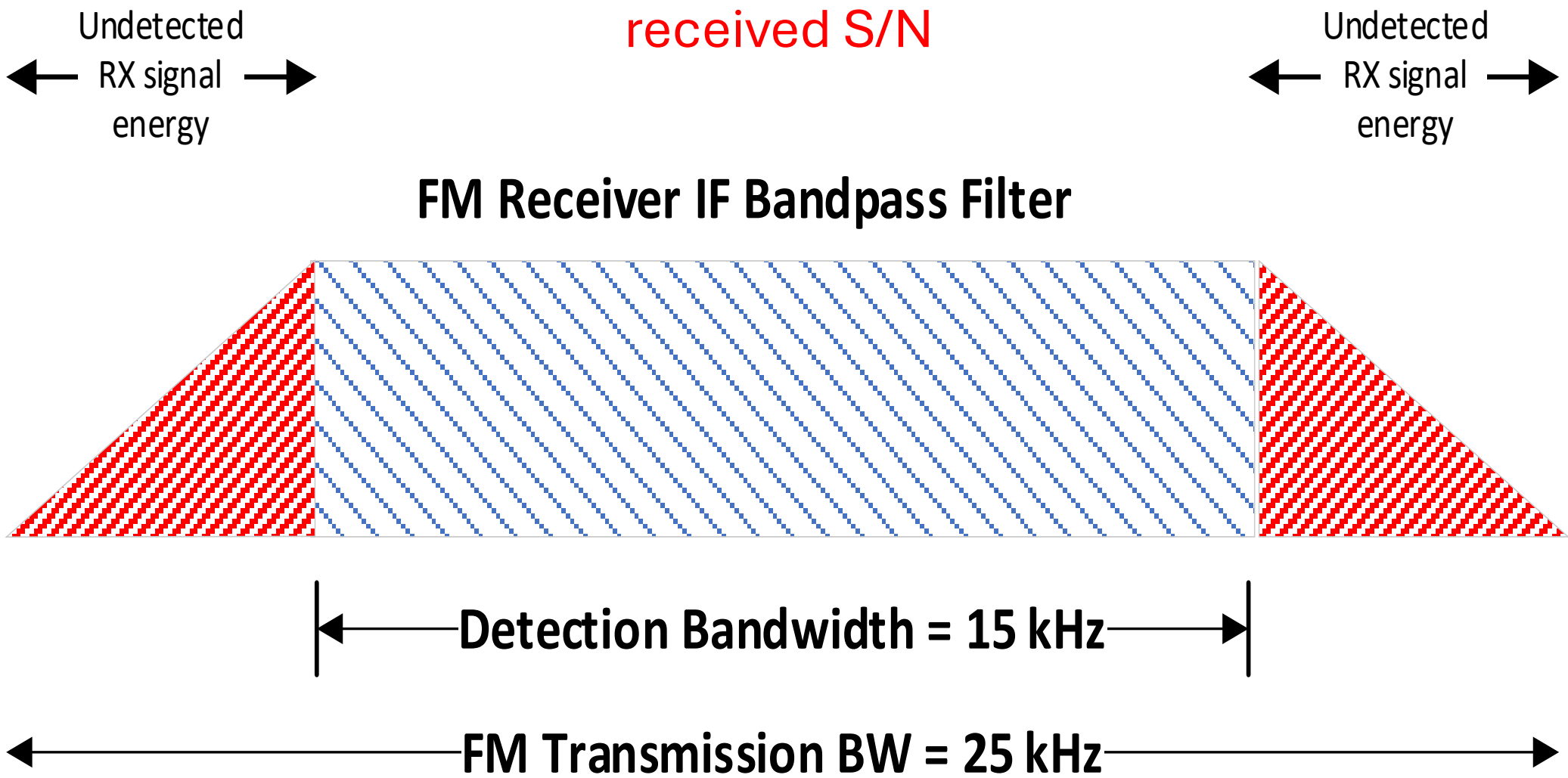
$BW_{FM\ TX} = 2 \times (2.5\ kHz + 5\ kHz) = 15\ kHz$

Overdriving the Transmit Audio Amplitude will cause the F_{dev} to exceed 5 kHz

A VARA FM NARROW carrier transmission greater than 15 or 16 kHz will result in lost or attenuated received signal energy needed to successfully demodulate and decode the data message.

In this example the transmit audio is over driven such that F_{dev} = 10 kHz
$BW_{FM\ TX}$ = 25 kHz

Results in reduced received S/N



So how do we keep this from happening?

ANSWER – We calibrate our VARA FM Winlink Station

How do we calibrate our VARA FM Winlink Station?

ANSWER – We run the Auto Tune operation

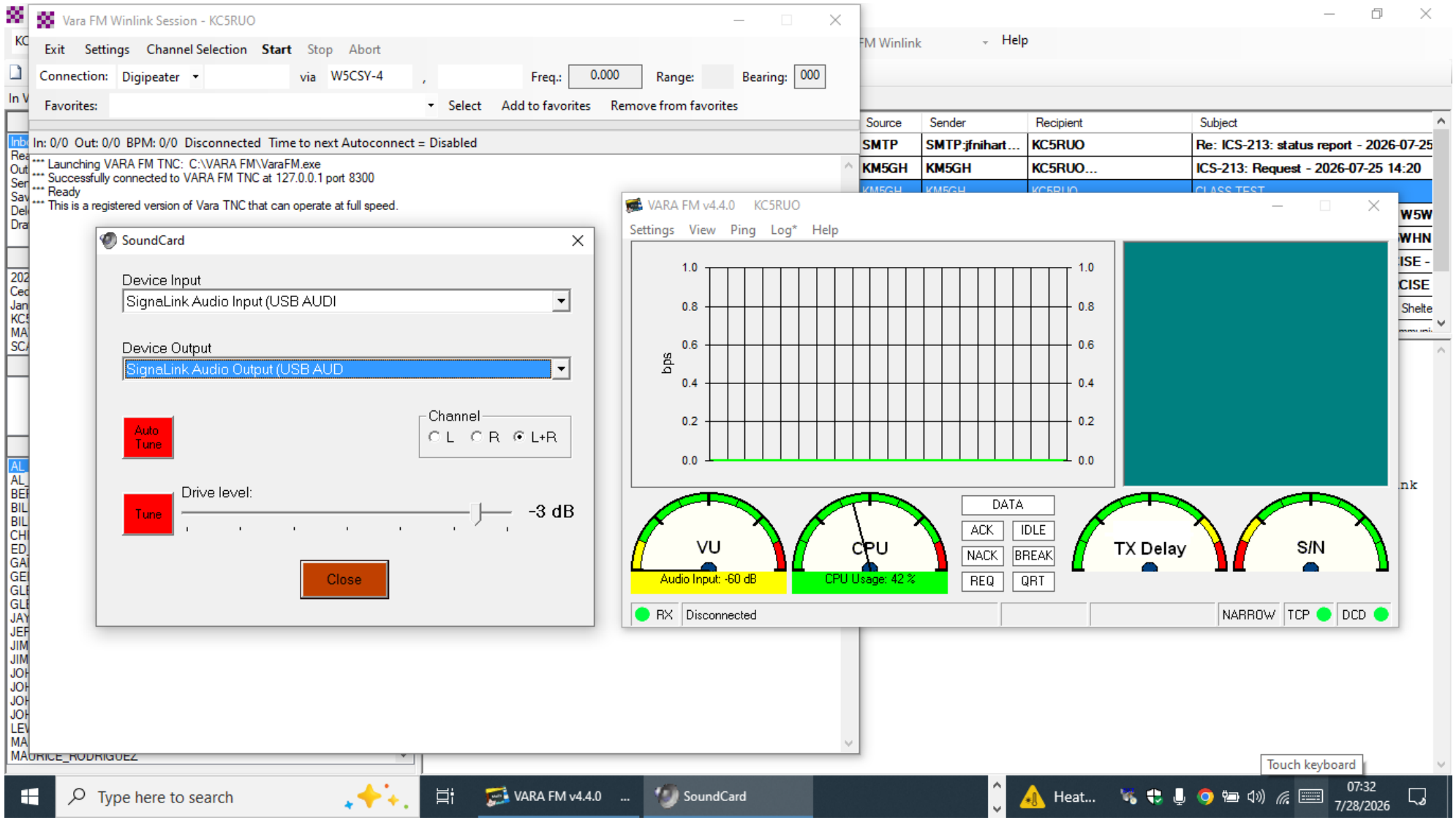
So what is the Auto Tune operation doing to help us calibrate our VARA FM WL Station

The Auto Tune function actually sets the Frequency Deviation of our transmitted signal

How? – while incrementally increasing the Terminal Node Controller (TNC) drive level it measures the resulting receive S/N at the distant end station

and then sets the TNC drive level that produces the highest S/N

Auto Tune gradually increases the Transmit Audio Drive Level by increasing the Terminal Node Controller's Drive Level



With each incrementally increasing transmit audio amplitude level the receive signal – to – noise (S/N) at the distant end station is measured and reported.

The transmit audio drive level is then “fine tuned” with adjustments the radio operator is instructed to make to the Microsoft Audio Output (SPEAKERS, PLAYBACK) sound setting or to the SignaLink Transmit Gain Control

When **APPROVED**, your station is fully calibrated

So what about VARA FM WIDE?

The F_{dev} for VARA FM WIDE should not exceed 3 kHz

Carson's Rule applies here as well:

Carson's Rule: $BW_{FM\ TX} = 2 \times (\text{Baseband Audio BW} + F_{dev})$

$BW_{FM\ TX} = 2 \times (\text{Baseband Audio BW} + 3\ \text{kHz})$

Deriving the VARA FM Winlink Baseband Audio Bandwidth
Baseband Audio BW = (symbol rate) x (number of carriers)

- The bandwidth of the modulated audio carrier is approximately = symbol rate
- **VARA FM WIDE Level 13**
  - There are 116 modulated audio carriers being transmitted simultaneously during a message transmission.
  - The 116 carriers are Orthogonally Frequency Division Multiplexed (OFDM) together.
- Level 13 Baseband Audio BW ≈ 5000 Hz
- Baseband Audio BW = 42 Hz x 116 carriers
- Baseband Audio BW = 4872 Hz
- Maximum VARA FM WIDE Baseband BW with guard band on he left and right will be approximately 5000 Hz

VARA FM Speed Table

	VARA FM WIDE				VARA FM NARROW			
Level	Symbol Rate	Carriers	Mod.	Net Rate (bps)	Symbol Rate	Carriers	Mod.	Net Rate (bps)
1	42	14	4PSK	566	42	14	4PSK	566
2	42	29	4PSK	1188	42	29	4PSK	1188
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11	42	116	64QAM	19003	42	58	256QAM	12750
12	42	116	128QAM	22102				
13	42	116	256QAM	25210				

For **VARA FM WIDE** communications the frequency deviation should not exceed **3 kHz**

Therefore, using Carson's Rule

$BW_{FM\ TX} = 2 \times (5.0\ kHz + 3\ kHz) = 16\ kHz$