Transmitting with the USRP

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Traditional Transmitter

\[ x(t) \rightarrow \cos 2\pi f_c t \rightarrow x_{\text{mod}}(t) \]

Modulator (AM, FM, PSK)

- \( f \pm f_m \)
- \( f \pm f_c \)
Difference: Frequency shift occurs AFTER modulation (in USRP), not DURING modulation.
Narrowband FM Transmitter

- Basic GRC layout of NBFM Transmitter with sine wave signal source.
Gain Compression

**USRP 400 MHz DAUGHTER BOARD**

- **Measured Values**
- **Linear Region**

**Multiply Const**

*Constant: 9000*

**USRPs**
Narrowband FM Transmitter (Signal Levels)

Signal Source
- Sample Rate: 1
- Waveform: Cosine
- Frequency: 1000
- Amplitude: 1
- Offset: 0

Max level = 1

NBFM Transmit
- Audio Rate:
- Quadrature Rate:
- Tau: 7.5e-05
- Max Deviation: 5000

Max level = 1

Multiply Const
- Constant: 9000

Max level = 16384

USRP Sink
- Unit Number: 0
- Subdev Spec: Auto
- Frequency: 446500000
- Interpolation: Gain: 0
- Mux: 0x0
- Auto T/R: Ignore
- TX Enable: Enable
Sample rates / Interpolation

Assume maximum baseband frequency, \( f_m = 3\text{KHz} \) \( \Rightarrow \) \( f_{s1} \geq 6\text{KHz} \)

\[
BW = 2(\Delta f + f_m) = 2(5\text{K} + 3\text{K}) = 16\text{KHz} \Rightarrow f_{s2} \geq 32\text{KHz}
\]

\[
f_{s3} \geq 32\text{KHz}
\]

FPGA
Interpolation factor of up to 512 (must be multiple of 4)

DAC
Requires 128 M s/s
Sample rates / Interpolation

\[ f_{s_1} \geq 6 \text{ KHz} \]
\[ f_{s_2} \geq 32 \text{ KHz} \]
\[ f_{s_3} \geq 32 \text{ KHz} \]

Example 1:
\[ f_{s_1} : \text{ Pick } f_{s_1} = 8 \text{ KHz} \]
\[ \text{(factor of 128M s/s)} \]

\[ f_{s_3} : \text{ Minimum value of } \frac{128\text{M}}{512} = 250\text{K} \]

Pick \( f_{s_3} = 256\text{K} \) (multiple of 8K)

Use \( f_{s_2} = f_{s_3} = 256\text{K} \) (eliminate need for resampler)

Interpolation factor of up to 512 (must be multiple of 4)

FPGA

 Requires 128 M s/s

DAC
Sample rates / Interpolation

\[ f_{s1} \geq 6 \text{ KHz} \quad f_{s2} \geq 32\text{ KHz} \quad f_{s3} \geq 32\text{ KHz} \]

**Example 2:**
- \( f_{s1} \): Pick \( f_{s1} = 32\text{ KHz} \) (factor of 128M s/s)
- \( f_{s3} \): Minimum value of \( 128\text{M}/512 = 250\text{K} \)
  - Pick \( f_{s3} = 256\text{K} \) (multiple of 32K)
  - Use \( f_{s2} = f_{s3} = 256\text{K} \) (eliminate need for resampler)

**FPGA**: Interpolation factor of up to 512 (must be multiple of 4)

**DAC**: Requires 128 M s/s

Set interpolation on USRP to be \( 128\text{M}/256\text{K} = 500 \)
Final Design and Demo

**Audio Source**
- Sample Rate: 48KHz
- Device Name: 
- OK to Block: Yes

**Multiply Const**
- Constant: 20

**Rational Resampler**
- Decimation: 3
- Interpolation: 2
- Taps: 
- Fractional BW: 0

**NBFM Transmit**
- Audio Rate: 32000
- Quadrature Rate: 256000
- Tau: 7.5e-05
- Max Deviation: 5000

**Multiply Const**
- Constant: 9000

**USRP Sink**
- Unit Number: 0
- Subdev Spec: Auto
- Frequency: 446500000
- Interpolation: 500
- Gain: 0
- Mux: 0x0
- Auto T/R: Ignore
- TX Enable: Enable