# IERG3820 Communications Laboratory

# Experiment 5: Frequency Division Multiplexing

## Introduction:

Frequency Division Multiplexing is a common signal multiplexing techniques to share the same physical transmission channel to support multichannel applications. Multiple frequency carriers are employed to carry individual signals. Each signal channel occupies a limited bandwidth and it has to make sure all signal channels do not spectrally overlapped with the adjacent ones. Any spectral aliasing among adjacent channels definitely leads to severe degradation due to interference. At the receiving end, a particular channel is retrieved by filtering, via a bandpass filter centered at the respective carrier frequency and having a passband bandwidth wide enough to cover the signal bandwidth.

## Experimental Boards:

This experiment contains two sets of boards, one is for signal transmission and the other one is for signal reception. Three RF channels with Amplitude Modulation (AM) are used.

Experimental board at the *transmitter* side:

- (1 x BT1) Power Connector Board is at the top right corner.
- (3 sets BT2) RF Generator, it generates 300 kHz to 1MHz signal as the carrier of each channel. They are on the left. Frequency and Amplitude are adjustable.
- (3 sets x BT3) Audio Function Generator 100Hz to 5kHz are on the left, these boards generate Sine, Triangle and Square waves. Frequency, amplitude and offset can be adjusted. They are beside the RF Generators.
- (3 sets x BT4) Balanced Modulator for AM modulation. They are located at the top of both generators.
- (3 sets x BT5) Tuned Amplifier selects the specified bandwidth for the carrier.
- (1 x BT6) A Four-Channel MIXER. It combines all three RF channels into one output. It is on the right.
- (1 x BT7) A Spectrum Analyzer Driver. It is a buffer amplifier for matching the spectrum analyzer with 50ohm input.

Experimental board at the *receiver* side:

- (1 x BR1) Power Connector Board is at the top right corner.
- (4 sets x BR2) Tuned Amplifier selects specified bandwidth for the carrier. Three sets are preset for specified channel. One set is for tuning by the users.
- (3 sets x BR3) Balanced Modulator for AM de-modulation. They are at the center of Rx set.
- (1 x BR4) A 4 x 2$^{nd}$ order Low Pass Filter. Filter out the modulated signal.
- (1 x BR6) RF Generator, it generates 300kHz to 1MHz signal as the carrier of each channel. They are on the left. Frequency and Amplitude are adjustable.

# Procedure:

<u>Board at the Transmitter side</u>

1. Connect power to the experiment board. Connect the IDC-10 cable between power supply and Power Connector Board (BT1). This connector has got an open-slot mark to indicate direction. It provide +/-15V and +/-8V to the experimental board.

2. Prepare Carrier Signals.
   * *The input impedance of Spectrum Analyzer is 50 ohm. Don't connect the Spectrum Analyzer's input to any point on the board except TP72.*
   * *Setup Spectrum Analyzer before connecting to the board with BNC cable.*
   * *The follow is the Spectrum Analyzer initial setting, you need change the Spectrum Analyzer setting according to the measured signal.*

   - *Center frequency (FREQ) = 550 kHz*

     *(Note: The frequency halfway between the stop and start frequencies on a spectrum analyzer display is known as the center frequency)*
   - *SPAN = 250 kHz*

     *(Note: Span specifies the range between the start and stop frequencies, that is from left to right of display)*
   - *Resolution Bandwidth (RBW) = 300Hz (for RIGOL DSA815, press key "BW/Det" on Control part)*

     *(Note: RBW filter is the bandpass filter in the IF path that is applied to the input signal. It's the bandwidth of the RF chain before the detector (power measurement device). Smaller RBWs provide finer frequency resolution and the ability to differentiate signals that have frequencies that are closer together, that is it determines how close two signals can be and still be resolved by the analyzer into two separate peaks.)*
   - *Amplitude (AMPT) = Input Att.: 30dB and Ref Level: 20dBm*

   Connect BT2-1 TP21 'OUTPUT' to BT7 TP71 'INPUT' with long cable and connect BT7 TP72 'OUTPUT' to spectrum analyzer with BNC cable to measure it with Spectrum Analyzer. Connect BT2-1 TP21 'OUTPUT' to an oscilloscope channel. Press the KEY BT2-1 SW21 down for low frequency group (300 ~ 800 kHz).
   Adjust BT2-1 VR22 'GAIN' to ~0dBm and adjust BT2-1 VR21 to set frequencies as table.

| Board | Frequency | Amplitude |
|---|---|---|
| BT2-1 | 450 kHz | ~670 mVpp (~ 0 dBm) |
| BT2-2 | 550 kHz | ~670 mVpp (~ 0 dBm) |
| BT2-3 | 650 kHz | ~670 mVpp (~ 0 dBm) |

3. Prepare Modulating Signals. Connect BT3-1 TP31 'OUTPUT' to one of the oscilloscope channels and adjust VR31 and VR32, set BT3-1 TP31 as follows:

| Board | Waveform | Frequency | Amplitude | Offset |
|---|---|---|---|---|
| BT3-1 | Sine | 1 kHz | ~1.5Vpp | 0V |
| BT3-2 | Sine | 3 kHz | ~1.5Vpp | 0V |
| BT3-3 | Sine | 4 kHz | ~1.5Vpp | 0V |

4. Prepare Modulated Signals. Connect each BT2-1 TP21 'RF OUT' and BT3-1 TP31 'OUTPUT' to BT4-1 TP41 'CARRIER IN' and TP42 'MODULATION IN' respectively. Press SW41 down.

   Measure the modulated signals with Spectrum Analyzer and oscilloscope. Connect BT4-1 TP43 'OUTPUT POS' to the Spectrum Analyzer through SPECTRUM DRIVER BOARD (BT7 TP71). Connect BT4-1 TP44 'OUTPUT NEG' to oscilloscope.

   Adjust BT4-1 VR41 'NULL ADJ' to get 100% modulation with AM (*check at oscilloscope*) and adjust VR42 'GAIN ADJ' to set output to around -10dBm (*check at Spectrum Analyzer*) and with at least 40 dB difference to noise (SPAN=200 kHz).

   Repeat this step for all three RF channels.

5. Prepare Modulated Signals with Tuned Amplifier. Connect BT4-1 TP43 'OUTPUT POS' to BT5-1 TP51 'INPUT'. Monitor TP53 with spectrum analyzer.
   Adjust BT5-1 VR51 'FREQ.ADJ' to get the maximum output and both side bands to be same, it means that the Tuned Amplifier has peak response at this frequency (*carrier frequency 450kHz*). You may need to expand the SPAN of Spectrum Analyzer (SPAN=20 - 50 kHz) to observer the side bands, if both side bands are not the same, fine tune BT5-1 VR51 'FREQ.ADJ'.
   Repeat this step for all three RF channels.

6. Combine three RF channels into one output. Connect three BT5 boards, via TP53 'OUTPUT's, to any three 'INPUT's, TP61 ~ TP64 on BT6 board. Adjust each BT5's VR53 'AMP ADJ' and measure the BT6 'OUTPUT' TP65 with Spectrum Analyzer through SPECTRUM DRIVER BOARD BT7 TP71. Three modulated FDM channels 450 kHz, 550 kHz and 650 kHz are on the spectrum at the same time with the same power level.
   *Suggested Spectrum Analyzer setting:*
   *Center Frequency=550 kHz,*
   *SPAN=250 kHz,*
   *RBW=1 kHz. (RBW's key named: 'BW/Det' (resolution bandwidth))*
   *(You need to adjust the RBW in order to see the side bands of the 450kHz channel)*

<u>Board at the Receiver side</u>

7. Select specified channel from FDM signal. Connect BT6 TP65 'OUTPUT' to BR2-1 TP21 'INPUT'. Connect four BR2 boards' TP21 'INPUT's hand-in-hand and share with the signal from Transmitter side.

   Connect the Spectrum Analyzer to one of BR2's TP22 'OUTPUT's. Adjust BR2's VR21 'FREQ. ADJ' and VR22's 'AMP. ADJ' to set the specified channel output (Frequency channel) to be 15dB higher than others.

   Repeat this step for the three fixed frequencies' BR2; 450 kHz, 550 kHz and 650 kHz. Tuned Amplifier output (BR2 TP22) is the specified channel from the mixed FDM signal.

8. Demodulate a modulated signal. Connect BR2-1 TP22 'OUTPUT' (*A symmetric AM signal*) to BR3-1 TP32 'MODULATION IN'. Connect the carrier from BT2-1 TP21 to BR3-1 TP31 'CARRIER IN' (*long cable*).

   Let BR3-1 SW31 switch is at UP position, you will get a half wave signal with carrier at BR3-1 TP33 'OUTPUT POS'. Monitor both signals with two channels of the oscilloscope.

   Adjust BR3-1 VR32 "GAIN ADJ." to get a strong enough signal. The negative part of the symmetric signal is cancelled out by the Balanced Modulator (BR3).

9. Filter out the carrier from the half wave signal. Connect BR3-1 TP33 'OUTPUT POS' to BR4 TP41 'IN_1' and monitor TP42 'OUT_1' with an oscilloscope. The RF part of the modulated signal is filtered out by a low pass filter. Measure at BR-4 TP42 'OUT_1' signal; is it the same as the signal from BT3-1 TP31 'OUTPUT'?

   Repeat this step for the other two RF channels, 550 kHz and 650 kHz. Describe what you have studied about FDM.

   (*Beware the 4 Low Pass Filters at BR4 are in difference in cut-off frequencies*)

Optional questions:

10. Limitation of de-modulation with Balance Modulator. Repeat step-8 and replace *carrier* signal from BR6 TP61. Adjust the BR6 VR61 frequency to the RF channel you want. Could you get the original signal from demodulation? Explain your observations and suggest the solution with block diagrams. *(*Hint: It is impossible to regenerate a synchronized signal by another set circuit. Phase-locked loop (PLL) is one of the feasible solutions.)

11. Adjacent channel. In previous steps, the channel separation is 100 kHz. In this step, we try to place two channels closely together with 20 kHz and 10 kHz and check the output if they are too close. Repeat from step-2 to step-9, set BT2-1 to 530 kHz and 540 kHz with 20 kHz and 10 kHz channel separation. Remember you need to set BR2-1 to select new channel frequencies (530 kHz and 540 kHz).
    Describe your observations of the problem when the adjacent channels are too close to each other. Suggest your solution of channel separation of AM and FM modulation and explain your reasons. *(Hints: from the point of view of S/N ratio)*
    *Spectrum Analyzer setting: Center frequency=460 kHz, SPAN=50 kHz, RBW=300Hz.*