

# Compact transmission-line circuit for audio and microwave signals

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## Abstract

In this paper, a transmission line is proposed to propagate both audio and microwave signals. The input and output chokes at audio input and output paths isolate the microwave signal transmitting to audio input and output respectively. The proposed transmission line shows that audio and microwave signals can be mixed together in the same line, which reduces the size of print circuit board (PCB). This proposed transmission-line circuit can be designed in any transmission structures and it shows that the overall result is the same as individual result.

Keywords: transmission line, microstrip line, antenna, S-parameters

## 1. Introduction

Recent research on IoT applications [1]-[2] has been of interest to our daily life. Bluetooth application is one of the best solution in IoT applications because of its low power consumption. Wearable application is one of common use in IoT applications such as audio headsets [3] and sensing applications [2]. The devices, therefore, have to be small and flexible for wearable application. Antenna under 2.4 GHz industrial, scientific and medical (ISM) band is normally occupied one-third of space in the overall circuit even it is quarter-wavelength long in the length by the mirror image [4]. Minimizing the size of the circuit especially the antenna is still the main challenging research area. There are different methods to minimize the size of area as well as the cost [5]-[7]. In the wearable design, the circuit has to be broken into multiple small parts to fit and minimize the final application, therefore, multiple connections of cables/print circuit board (PCB) traces between different circuits are used. The cables/PCB traces may affect each other because of the EMI effect [8]. In this paper, a transmission line is proposed to propagate both audio and microwave signals. This proposed line reduces the overall number of wires in the circuit which reduces the PCB size. Experimental shows that result is the same as individual result.

## 2. Transmission line design

Fig. 1 is the traditional circuit for audio and microwave signals. In traditional design, the lines for audio and microwave signals are designed and routed individually in PCB layout. These two lines should be isolated to prevent any EMI effect, therefore, certain space is consumed due to their isolation. The proposed circuit is shown in Fig. 2, which is the traditional transmission line [9]. The structure of this transmission line used can be microstrip, parallel strips lines, or others, [9]. The input and output chokes at audio input and output paths in Fig. 2 are added to isolate the microwave signal transmitting to audio input and output respectively because the impedances ( $Z_{in}$ ) looking to the audio input and output are very large (infinity) shown in Fig. 3. The input and output of microwave circuits normally have the matching networks which are narrow band circuits for particular frequency range in Fig. 2, therefore, there is no leakage of audio signal to the microwave circuits.

## 3. Experimental results

The circuit in Fig. 2 was implemented on FR4 substrate of 0.8 mm thickness, while high-Q surface mount inductors were used as RF choke (RFC) and the microstrip line was used as transmission line because of its simple structure. The fabricated circuit is shown in Fig. 4. The speaker was replaced by the 33 ohm resistor as load ( $R_2$ ) which is the common resistance of earphone's speakers and no matching networks were used in this fabricated circuit. And 1000 ohm resistor is added at input choke as output impedance ( $R_1$ ) of audio amplifier. Fig. 5 and 6 show the S-parameters of the fabricated circuit. Fig. 5 shows that the return loss is better than 15 dB from 1 to 5 GHz. Fig. 5 shows the insertion loss is lower than 0.5 dB from 1 to 4 GHz. The increase in insertion loss at higher

frequency in Fig. 6 is due to the loss of FR4 substrate, which is depended on the length of the transmission. High-frequency substrate and other transmission line structures can be used to provide lower loss in high frequency. The operating frequency of this circuit covers IoT applications in GPS, 2.4 GHz ISM band and the common 3GPP WCDMA and LTE bands as well as 5G NR (New Radio) sub-6 GHz bands. Fig. 7 shows the 1000 Hz audio signal at the audio input and output and it shows that there is no significant loss in this audio signal after passing through the circuit in Fig. 4.

#### 4. Conclusion

Compact transmission line integrated audio and microwave signals for simultaneous transmission has been proposed. The principle behind the operation of this design and the experimental results have been presented. The results demonstrate that the circuit can reduce the overall number of wires which reduces the PCB size. Experimental shows that result is the same as individual results.

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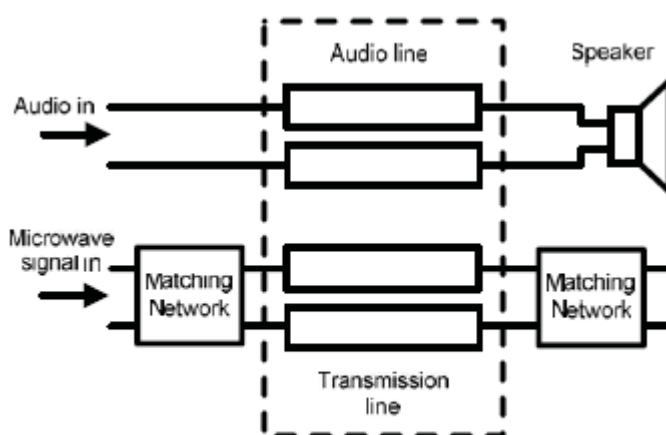


Fig. 1. Traditional circuits for audio (top) and microwave (bottom) signals.

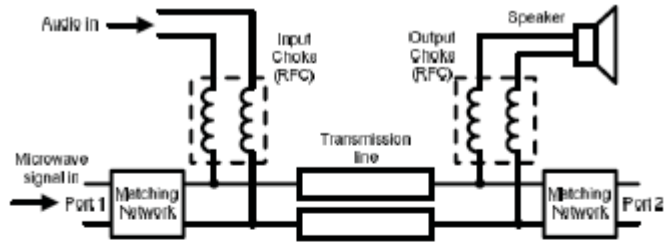


Fig. 2. Proposed circuit for simultaneous transmission.

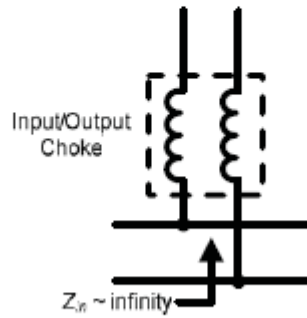


Fig. 3 The impedance ( $Z_{in}$ ) of microwave signal looking to audio input and output paths.

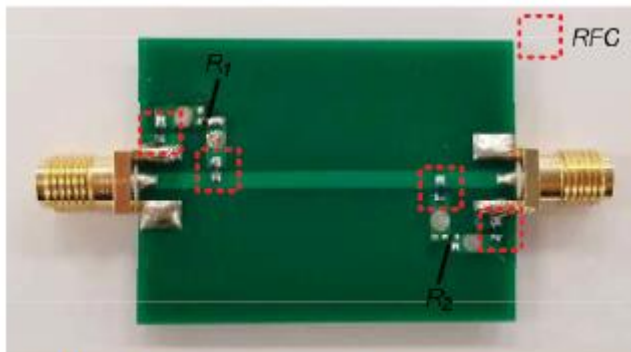


Fig. 4 Photograph of fabricated circuit.

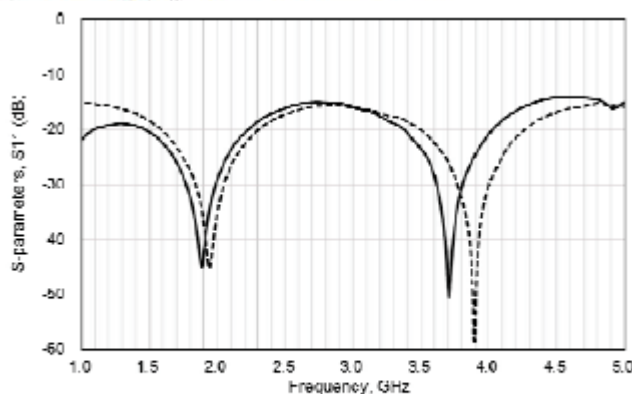


Fig. 5 Simulated (dashed line) and measured (solid line) S-parameters,  $S_{11}$ .

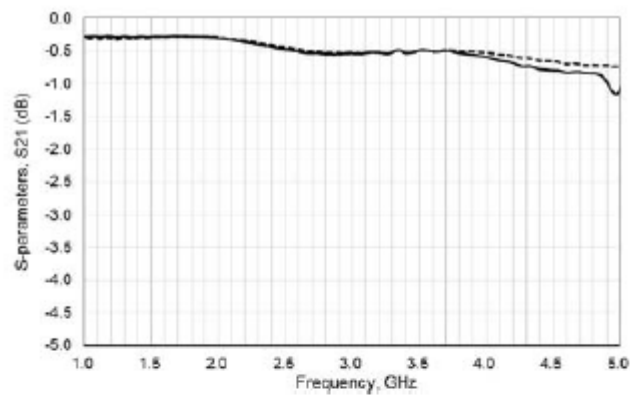


Fig. 6 Simulated (dashed line) and measured (solid line)  $S$ -parameters,  $S_{21}$ .

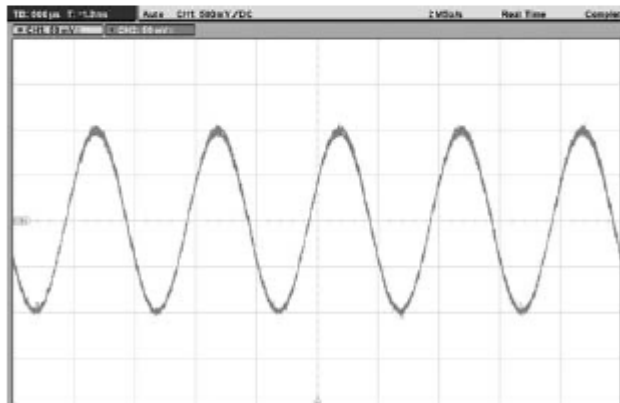


Fig. 7 The 1000 Hz audio signal at the audio input and output with 33 ohm resistor as load.